



PATENT APPLICATION #13

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the application of:

Attorney Docket No.: 2950.16US02

Bi et al.

Confirmation No.: 9146

Application No.: 09/715,935

Examiner: E. B. Fuller

Filed: November 17, 2000

Group Art Unit: 1762

For: COATING FORMATION BY REACTIVE DEPOSITION

BRIEF FOR APPELANTS

Box AF
Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

This is an appeal from an Office Action dated April 19, 2002, in which claims 18-61 were finally rejected. A Notice of Appeal was filed on July 19, 2002.

REAL PARTY IN INTEREST

NeoPhotonics Corporation, a corporation organized under the laws of the state of Delaware, and having offices at 49040 Milmont Drive, Fremont, California, has acquired the entire right, title and interest in and to the invention, the application, and any and all patents to be obtained therefor, as per the Assignment, a copy of which is attached in Appendix B. Note that NeoPhotonics Corporation was formerly called NanoGrain Corporation and has retained the name "NanoGram Corporation" as the name of a wholly owned subsidiary following a formal name change.

RELATED APPEALS AND INTERFERENCES

Applicants are aware of no related appeals.

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STATUS OF THE CLAIMS

Claims 18-61 stand rejected. The pending claims are listed in Appendix A.

STATUS OF AMENDMENTS

All Amendments have been entered with the filing of the Appeal.

SUMMARY OF INVENTION

The present invention relates to the formation of coating from a product particle stream that is formed in a reactive flow. See, for example, page 9, line 26 to page 10, line 12 of the specification. Thus, the reactants react to form product particles that are directed to a substrate for coating without the need to collect the particles. In some embodiments, the product particles are formed as a result of a reaction driven by a radiation beam. The use of a radiation beam provides for producing particles with desirable particle properties, in particular for some embodiments, very small particles and highly uniform particles. See, for example, page 17, lines 17-24 and page 51 to page 53, line 12. The approach is highly versatile with respect to the formation of particles having selected compositions. See, for example, page 53, line 27 to page 56, line 19.

In some embodiments, the reactant inlet is elongated in one direction to produce a corresponding elongated reactant stream. See, for example, page 38, lines 7-21 and Fig. 19. The elongated reactant stream can be used to form an elongated product particle stream that directs a line of particles along a substrate during the coating process. By properly accounting for the line of particles in the coating process, a highly efficient and rapid coating process can be carried out. See, for example, page 45, lines 3-15. In particular, in some embodiments very high coating rates can be achieved for very high quality coatings.

In further embodiments, the reactant inlet can move relative to a fixed substrate. See, for example, page 42, lines 23-28. These embodiments allow for a fixed substrate which does not

deflect the flow due to its motion. In some embodiments, multiple product streams can be deposited on a single substrate. See, for example, page 64, lines 10-26. These multiple deposition processes can be advantageous for the deposition of multiple layers of material.

In particular, the coating processed described herein can be used, in particular, for the formation of optical coatings. See, for example, page 65, line 4 to page 68, line 17. The optical coatings can be constrained to selected portions of substrates for the formation of optical devices.

ISSUES

1. Whether claims 18-29, 33-42, 44, 46-51, 55-57 and 59-61 are obvious under 35 U.S.C. § 103(a) over U.S. Patent 6,280,802 to Akedo et al. in view of U.S. Patent 5,958,348 to Bi et al.?
2. Whether claims 30, 43, 45, 52 and 58 are obvious under 35 U.S.C. § 103(a) over U.S. Patent 6,097,144 to Lehman in view of U.S. Patent 6,280,802 to Akedo et al. and U.S. Patent 5,958,348 to Bi et al. in further view of WO 99/23189 to Kambe et al.?
3. Whether claims 31 and 32 are obvious under § 103(a) over U.S. Patent 6,074,888 to Tran et al., in view of U.S. Patent 6,097,144 to Lehman et al. and further in view of U.S. Patent 6,280,802 to Akedo et al. and U.S. Patent 5,958,348 to Bi et al. in view of WO 99/23189 to Kambe et al.?
4. Whether claims 18-29, 39-41, 50 and 51 are obvious under § 103(a) over U.S. Patent 6,032,871 to Börner et al. in view of U.S. Patent 5,958,348 to Bi et al.?
5. Whether claims 53 and 54 are obvious under § 103(a) over U.S. Patent 6,032,871 to Börner et al. in view of U.S. Patent 6,280,802 to Akedo et al. and U.S. Patent 5,958,348 to Bi et al.?

GROUPING OF CLAIMS

1. Claims 18-21, 23, 25, 28-30, 43 and 44 form a first claim group directed to a method of coating a substrate.

2. Claims 22, 24, 26, 33, 35-38, 45-49 and 57 form a second claim group directed to a method for coating a substrate comprising reacting an elongated reactant stream.
3. Claim 27 forms a third claim group directed to a method for coating a substrate in which the reactant inlet moves relative to the substrate.
4. Claims 31 and 32 form a fourth claim group directed to a method for forming an optical component on a substrate surface.
5. Claims 34, 39-41, 50-52, 55, 56 and 58-61 form a fifth claim group directed to a method for coating a substrate at deposition rates within particular ranges.
6. Claims 42, 53 and 54 form a sixth claim group directed to a method for coating a substrate with multiple product streams.

ARGUMENT

I. LEGAL BACKGROUND

A. The Examiner bears the burden of demonstrating nonobviousness.

The Applicants note that the patent office has the burden of persuasion in showing that the Applicants are not entitled to a patent. "[T]he conclusion of obviousness vel non is based on the preponderance of evidence and argument in the record." In re Oetiker, 24 USPQ2d 1443, 1445 (Fed. Cir. 1992). The patent office has the ultimate burden of persuasion in establishing that an applicant is not entitled to a patent. Id. at 1447, concurring opinion of Judge Plager. **"The only determinative issue is whether the record as a whole supports the legal conclusion that the invention would have been obvious."** Id.

"In rejecting claims under 35 U.S.C. §103, the examiner bears the initial burden of presenting a prima facie case of obviousness." In re Rijckaert, 28 USPQ2d 1955, 1956 (Fed. Cir. 1993). Prima facie obviousness is not established if all the elements of the rejected claim are not disclosed or suggested in the cited art. In re Ochiai, 37 USPQ 1127, 1131 (Fed. Cir. 1995). ("The

test for obviousness *vel non* is statutory. It requires that one compare the claim's 'subject matter as a whole' with the prior art 'to which said subject matter pertains.'). See also, MPEP 2143.03 "All Claim Limitations Must Be Taught or Suggested," citing In re Royka, 180 USPQ 580 (CCPA 1974). "It is impermissible, however, to simply engage in a hindsight reconstruction of the claimed invention, using applicant's structure as a template and selecting elements from references to fill the gaps." In re Gorman, 18 USPQ2d 1885, 1888 (Fed. Cir. 1991).

If the Examiner fails to establish a prima facie case of obviousness, the obviousness rejection must be withdrawn as a matter of law. In re Ochiai, 37 USPQ at 1131 ("When the references cited by the examiner fail to establish a prima facie case of obviousness, the rejection is improper and will be overturned.").

B. There Must Be Motivation In The Art To Modify The Teachings Of the Cited References

The motivation, or suggestion, to combine references must be either explicitly or implicitly in the references or knowledge "generally available to one of ordinary skill in the art." See, MPEP § 2143.01. Furthermore, "[t]he test for an implicit showing is what the combined teachings, knowledge of one of ordinary skill in the art, and nature of the problem to be solved as a whole would have suggested to those of ordinary skill in the art." See, MPEP §2143.01 (quoting In re Kotzab, 55 USPQ2d 1313, 1317 (Fed. Cir. 2000)).

The Federal Circuit has provided considerable guidance on establishing obviousness of a claim based on a combination of references. "Our case law makes clear that the best defense against hindsight-based obviousness analysis is the rigorous application of the requirement of a teaching or motivation to combine the prior art references." Ecolochem Inc. v. Southern Edison, 56 USPQ2d 1065, 1073 (Fed. Cir. 2000). "Therefore, '[w]hen determining the patentability of a claimed invention which combines two known elements, 'the question is whether there is something in the prior art as a whole to suggest the desirability, and thus the obviousness, of

making the combination.' " *Id.* (quoting *In re Beattie*, 24 USPQ2d 1040, 1042 (Fed. Cir. 1992)(quoting *Lindemann Maschinenfabrik GmbH v. American Hoist and Derrick Co.*, 221 USPQ 481, 488 (Fed. Cir. 1984))). "In order to prevent a hindsight-based obviousness analysis, we have clearly established that the relevant inquiry for determining the scope and content of the prior art is whether there is a reason, suggestion, or motivation in the prior art or elsewhere that would have led one of ordinary skill in the art to combine the references." *Ruiz v. A.B. Chance Co.*, 57 USPQ2d 1161, 1167 (Fed. Cir. 2000). **"The test is not whether one device can be an appropriate substitute for another."** *Id.* (emphasis added). In *Ruiz*, the Federal Circuit overturned a district court holding that "it would have been obvious to combine screw anchors and metal brackets, because the need for a bracket 'was apparent.'" *Id.*

When the modification of an apparatus renders the apparatus "inoperative for its intended purpose," the reference teaches away from the suggested modification. *In re Gordon*, 221 USPQ 1125, 1127 (Fed. Cir. 1984). "If when combined, the references 'would produce a seemingly inoperative device,' then they teach away from their combination." *Tec Air Inc. v. Denso Manufacturing Michigan Inc.*, 52 USPQ2d 1294, 1298 (Fed. Cir. 1999)(citing *In re Sponnoble*, 160 USPQ 237, 244 (CCPA 1969)).

C. The References Must Provide A Reasonable Expectation Of Success

While a reference is prior art for all that it teaches, references along with the knowledge of a person of ordinary skill in the art must be enabling to place the invention in the hands of the public. *In re Paulsen*, 31 USPQ2d 1671, 1675 (Fed. Cir. 1994). See also *In re Donohue*, 226 USPQ 619, 621 (Fed. Cir. 1985). "The consistent criterion for determination of obviousness is whether the prior art would have suggested to one of ordinary skill in the art that this process should be carried out and would have a reasonable likelihood success, viewed in light of the prior art." *Micro Chemical Inc. v. Great Plains Chemical Co.*, 41 USPQ2d 1238, 1245 (Fed. Cir. 1997)(quoting *In Re Dow Chemical Co.*, 5 USPQ2d 1529, 1531 (Fed. Cir. 1988)).

D. The References Must Teach Or Suggest All Of The Claim Elements

"To establish prima facie obviousness of a claimed invention, all of the claim limitations must be taught or suggested by the prior art." MPEP 2143.03.

II. REJECTIONS UNDER 35 U.S.C. § 103(a) OVER AKEDO ET AL. AND BI ET AL.

The Examiner rejected claims 18-29, 33-42, 44, 46-51, 55-57 and 59-61 under 35 U.S.C. § 103(a) as being unpatentable over U.S. patent 6,280,802 to Akedo et al. (the Akedo patent) in view of U.S. patent 5,958,348 to Bi et al. (the Bi patent). A copy of the Akedo patent is provided in Appendix C, and a copy of the Bi patent is provided in Appendix D.

The Examiner cited the Akedo patent for disclosing a film forming apparatus that directs a particle stream at a substrate. Advisory Action of 6/28/2002 at page 2; and Office Action of 10/22/2001 at page 4. The Examiner cited the Bi patent for disclosing a process capable of supplying a flow of ultrafine-particles for the Akedo apparatus. More specifically, the Examiner asserted that "[t]o use the particle-production process of Bi in place of the aerosolizing chamber in figure 1 of Akedo, or to supply the feed into figure 3, would have been obvious at the time the invention was made to a person having ordinary skill in the art as the particle stream leaving the reactor of Bi comprises nanoparticles and inert gases and therefore is an aerosol." Advisory Action of 6/8/2002 at page 3. The Examiner has failed to establish a prima facie case of obviousness with respect to this rejection, because there is no motivation to combine the references in the manner suggested by the Examiner, because the combination of the references suggested by the Examiner yields an inoperable or incompatible system, because the references do not provide a reasonable expectation of success, and/or because claimed features are not taught or suggested by the cited references. Applicants respectfully request reconsideration of the rejection based on the following comments.

A. Group 1 Claims

Claims 18-21, 23, 25, 28-29 and 44 related to a method of coating a substrate.

With respect to the motivation to combine the references, there is no explicit or implicit motivation to combine the references. Concerning explicit motivation, the Examiner suggests that the requisite motivation to combine the references is a reduction in steps and the "efficient use of resources at high production capacity without sacrificing particle quality." Office Action of 4/19/2002 at page 3. With regard to the alleged motivation due to a "reduction in steps," there is no evidence of record that states which step(s) would be removed. Applicants assume *arguendo* that this alleged reduction in steps presumably relates to the step of the transfer of particles from a particle collector of the Bi apparatus to the powder reservoir of the Akedo reference. However, there is no evidence of record (either in an affidavit under 37 C.F.R. 1.104(d)(2) or in a cited reference) that this collection and transfer step is burdensome or that this would be a desirable step to avoid. In fact, the references themselves suggest that this may be a desirable step, in that the combined references merely suggest the production of particles with the Bi apparatus, followed by the subsequent transfer of the powders/particles to the Akedo apparatus, yielding no reduction in steps.

With regard to the alleged motivation based on "efficient use of resources," the benefits of the efficient use of resources that result from the use of the Bi apparatus are obtained in full if the particles are collected from the Bi apparatus and transferred to the Akedo apparatus. Moreover, any motivations would be offset by efforts that would be required to perform the dramatic redesign of the cited apparatuses to have them function together in the substitutions suggested by the Examiner. The references do not provide any guidance on this reconstruction. In addition, there is no evidence of record (either in an affidavit under 37 C.F.R. 1.104(d)(2) or in a cited reference) that a person of ordinary skill in the art would consider a particle generation apparatus as a reasonable substitute within an apparatus that uses powders to form coatings.

Furthermore, there is no implicit motivation since the references suggest the sequential use of the apparatuses first to produce particles and then to perform coating with the resulting powder. Thus, the Examiner has not shown any motivation, either explicitly or implicitly, in the references for substituting Bi's production apparatus directly for the aerosolizing chamber in Akedo, nor has the Examiner provided any motivation for combining the particle production process of Bi to supply the inlet feed of Akedo. Rather, the Examiner has clearly engaged in improper hindsight reasoning since the only motivation to combine the references is provided by Applicants' present specification. Thus, there is neither explicit nor implicit motivation that is sufficient to support a prima facie case of obviousness based on the combination of the Bi reference and the Akedo reference. Accordingly, withdrawal of the obviousness rejection based on the combination of the Bi reference and the Akedo reference is required by law, and hereby requested by the Applicants.

Furthermore, even assuming that the references are properly combinable, the specific combination from the teachings of the references that is suggested by the Examiner yields an inoperable or internally incompatible system. With respect to the combination of the structures disclosed in the references, the Examiner has changed his basis for combining the apparatuses throughout prosecution. Yet, each basis for combining the references fails to resolve the problem that the combination apparatus yields an inoperable or internally incompatible system, based on the cited references' disclosed embodiments' requirements for (a) an ionizing gas being in the stream (required by the Akedo apparatus, but not disclosed by, and potentially destructive to, the Bi apparatus) and (b) different operating pressures ("several Torr or lower" for the Akedo apparatus, and "10 torr to 500 torr" as an operating pressure for the disclosed embodiments of the Bi apparatus).

Initially, in the Office Action of October 22, 2001 at page 4, the Examiner suggested that it would be obvious to replace the aerosolizing chamber of the Akedo patent with the Bi

apparatus. In the Amendment of January 22, 2002, Applicants noted that there was no motivation to substitute the Bi apparatus for the aerosolizing chamber of the Akedo apparatus. In particular, Applicants noted that the Akedo patent does not teach how to modify the deposition conditions if the particles were produced in situ.

Then, in the Office Action of 4/19/2002 at pages 12 and 13, the Examiner asserted that the input stream in figures 6, 8 and 9 in the Akedo patent has an input stream that can be replaced with the stream of nano-sized particles generated in the Bi apparatus. Applicants noted in the Amendment of June 19, 2002 that this argument is incorrect because figures 6, 8 and 9 of the Akedo patent require the input stream to contain ultrafine particles and ionized gas. The Bi patent does not teach a particle stream with ionized gas, and therefore the combination suggested by the Examiner does not follow from the teachings of the references.

In the Advisory Action of June 28, 2002 on page 2, the Examiner agreed "that gas inlet flow 23 of Akedo requires a mixture of ionized gas and aerosolized ultrafine particles; additionally Bi contains no indication of ionizing gas being in the stream." Then, the Examiner reverted back to an argument based on Fig. 1 of the Akedo patent by noting that the particles from the aerosolizing chamber of Fig. 1 are combined later with an ionized gas.

The Akedo patent however teaches a particular configuration with an aerosolizing chamber 21 leading to a nozzle 4 to form an ultrafine particle stream. See, for example, column 6, lines 35-48. The properties of the particle stream are controlled in part by controlling the pressure in the aerosolizing chamber, see column 4, lines 44-49. The "vacuum chamber 20" is operated at a pressure of "several Torr or lower," see lines 41-43. **In contrast**, the Bi patent teaches one embodiment of its apparatus having an operating pressure of 10 torr to 500 torr. See column 4, lines 65-67. The Bi patent further teaches that the particle properties depend on the reaction conditions including chamber pressure, see, for example, column 4, lines 60-65. Applicants note that the examples of the present application were performed at pressures of 350

torr and 500 torr. The Examiner has not explained how to account for these pressure differences at which the apparatuses operate.

Accordingly, the specific combination from the teachings of the references that is suggested by the Examiner yields an inoperable or internally incompatible system. Thus, the combination of the Bi reference and the Akedo reference is not sufficient to support a prima facie case of obviousness. Accordingly, withdrawal of the obviousness rejection based on the combination of the Bi reference and the Akedo reference is required by law, and hereby requested by the Applicants.

In addition, combining the above-mentioned references as suggested by the Examiner does not provide a reasonable expectation of success. It is well settled that the prior art can not render claims prima facie obvious unless the modification or combination suggested by the Examiner provides a reasonable expectation of success. See, MPEP § 2143.02 (citing In re Merck & Co., Inc., 231 USPQ 375 (Fed. Cir. 1986)). The combination suggested by the Examiner is **at most** an invitation to experiment. Specifically, the Akedo patent focuses exclusively on the deposition of particles, and thus does not provide any indication of how the conditions used for the deposition of particles from the aerosolizing chamber would or could be modified if the particles were produced in a flow used for the coating process. Similarly, the Bi patent describes the conditions appropriate for the production and collection of particles. There is no discussion of whether or not modification would be appropriate for the coating of the particles onto a substrate. As noted above, the pressure conditions used in the two apparatuses are different. Thus, there are significant gaps in the disclosures such that there would be no reasonable expectation of success in combining the disclosures as suggested by the Examiner.

With respect to Applicants' arguments regarding the combination of the Akedo apparatus and the Bi apparatus, the Examiner indicated that Applicants' arguments are unpersuasive because the Akedo patent in figures 1 and 3 "teaches that the aerosolized particles and ionized

gas may be supplied separately.” Advisory Action of 6/28/2002 at page 3. However, the Akedo patent does not provide any indication of how or if the conditions used for the deposition of particles from the aerosolizing chamber should be modified if the particles were produced in a flow used for the coating process. In addition, the Examiner has not provided a reasonable explanation or reference that describes how the product stream from Bi could be incorporated or modified to supply the feed line in figures 1 or 3 of the Akedo patent. The teachings of the cited references fall far short of providing teachings that result in a reasonable likelihood of success with respect to a person of ordinary skill in the art practicing Applicants' presently claimed invention.

Accordingly, the specific combination from the teachings of the references that is suggested by the Examiner has no reasonable expectation of success. Thus, the combination of the Bi reference and the Akedo reference is not sufficient to support a prima facie case of obviousness. Accordingly, withdrawal of the obviousness rejection based on the combination of the Bi reference and the Akedo reference is required by law, and hereby requested by the Applicants.

Since there is no motivation to combine the references as suggested, since the combination of the references suggested by the Examiner yields an inoperable or incompatible system, and since there is no reasonable expectation of success, the Examiner has failed to make out a prima facie case of obviousness. Accordingly, withdrawal of the obviousness rejection of the Group 1 claims (claims 18-21, 23, 25, 28-29, and 44) based on the combination of the Bi reference and the Akedo reference is required by law, and hereby requested by the Applicants.

B. Group 2 Claims

Claims 22, 24, 26, 33, 35-38, 46-49 and 57 relate to a method for coating a substrate comprising reacting a reactant stream where the reactant stream is elongated in a direction along

the propagation of the radiation beam. As noted above with respect to Group 1 claims, there is no motivation to combine the cited references in the manner suggested by the Examiner with respect more generally to Applicants' coating process, the combination of the references suggested by the Examiner yields an inoperable or incompatible system, and the combined disclosures do not provide a reasonable expectation of success with respect generally to Applicants' coating processes. These arguments apply equally to the present Group 2 claims.

Furthermore, the claimed features of Group 2 claims are not taught or suggested by the cited references, taken alone or in combination, and this provides an additional basis for no reasonable expectation of success. The Akedo patent does not disclose, teach or suggest a method for coating a substrate comprising reacting a reactant stream, where the reactant stream is elongated in a direction along the propagation of the radiation beam. Moreover, the Akedo patent does not disclose or suggest any type of reactant stream, because the Akedo patent is directed towards substrate coating technology, not particle production technology. While the Bi patent discloses a reactant stream elongated in the direction along the propagation of the radiation beam, the Bi patent does not disclose, teach or suggest using this feature in a substrate coating process. Furthermore, the cited references do not teach or suggest how to modify a coating process to account for an elongated stream. Since the Akedo patent does not disclose coating with an elongated reactant stream and the Bi patent does not disclose how to perform coating as claimed, the combined disclosures do not lead to the inventions of claims in Group 2. This provides a further basis for showing that there is no a reasonable expectation of success in the combination of these cited references.

Because of the shortcomings described in the previous section and the particular shortcoming of the references with respect to performing a coating process with an elongated reactant stream, the Examiner has failed to present a case of prima facie obviousness of claims 22, 24, 26, 33, 35-38, 46-49 and 57 over the combined teachings of the Akedo patent in view of

the Bi patent. Accordingly, withdrawal of the obviousness rejection of the Group 2 claims (claims 22, 24, 26, 33, 35-38, 46-49 and 57) based on the combination of the Bi reference and the Akedo reference is required by law, and hereby requested by the Applicants.

C. Group 3 Claims

Claim 27 relates to a method for coating a substrate in which the reactant inlet moves relative to the substrate. As noted above with regard to the Group 1 claims, there is no motivation to combine the cited references in the manner suggested by the Examiner, the combination of the references suggested by the Examiner yields an inoperable or incompatible system, and the combined disclosures do not provide a reasonable expectation of success. These arguments apply equally to the present Group 3 claim. Furthermore, the claimed features of the Group 3 claims are not taught or suggested by the cited references, taken alone or in combination, and this provides an additional basis for no reasonable expectation of success.

With respect to the claimed feature of moving the reactant inlet relative to the substrate, the references, taken alone or in combination, do not teach such an embodiment. As the Akedo patent is described by the Examiner, the coating is performed through the nozzle of the Akedo apparatus. This nozzle does not seem to move when the particle generation apparatus is moved. Nothing in the Bi patent corrects this clear deficiency of the Akedo patent, as the Bi patent does not teach a method for coating a substrate, let alone such a method where the reactant inlet moves relative to the substrate. This provides a further basis for showing that there is no reasonable expectation of success in the combination of these cited references.

The Examiner in the Office Action of April 19, 2002 on page 4, asserts that the entire apparatus can be moved to result in moving the reactant inlet. However, this analysis has at least two major flaws. First, moving the apparatus (based on the Examiner's suggestion for combining the apparatuses) does not move the substrate relative to the particle stream. As described above,

the coating is performed through the nozzle of the Akedo apparatus. This nozzle does not seem to move when the particle generation apparatus is moved.

Second, the Bi patent does not suggest that the apparatus can be moved during operation. As described in the Bi patent, the apparatus' bulk is significant and involves optical pathways that may be sensitive with respect to motion. The lasers themselves are large and heavy as are the chamber and the pumps. There is not evidence of record (either in an affidavit under 37 C.F.R. 1.104(d)(2) or in a cited reference) to support the Examiner's suggestion. The Examiner's suggestion does not seem to be reasonably based on any teachings in the references or in the general skill in the art.

Because of the shortcomings described in the Group 1 claims section and the particular shortcomings of the references with respect to method for coating a substrate in which the reactant inlet moves relative to the substrate, the Examiner has failed to present a case of prima facie obviousness of claim 27 over the combined teachings of the Akedo patent in view of the Bi patent. Accordingly, withdrawal of the obviousness rejection of the Group 3 claim (claim 27) based on the combination of the Bi reference and the Akedo reference is required by law, and hereby requested by the Applicants.

D. Group 5 Claims

Claims 34, 39-41, 50, 51, 55, 56, 60 and 61, generally relate to methods for coating a substrate where the amount of particles deposited on the substrate is at least 5 or at least 25 grams per hour. As noted above with regard to the Group 1 claims, there is no motivation to combine the cited references in the manner suggested by the Examiner, the combination of the references suggested by the Examiner yields an inoperable or incompatible system, and the combined disclosures do not provide a reasonable expectation of success. These arguments apply equally to the present Group 5 claims. Furthermore, the claimed features of the

Group 5 claims are not taught or suggested by the cited references, taken alone or in combination, and this provides an additional basis for no reasonable expectation of success.

The Akedo patent does not teach, disclose or suggest a method for coating a substrate where the amount of particles deposited upon the substrate is at least 5 or at least 25 grams per hour. Nothing in the Bi patent corrects this clear deficiency of the Akedo patent, as the Bi patent does not teach a method for coating a substrate, let alone such a method where the amount of particles deposited upon the substrate is at least 5 or at least 25 grams per hour. This provides a further basis for showing that there is no reasonable expectation of success in the combination of these cited references.

The Examiner asserted in the Office Action of April 19, 2002, that these features "are within the skill in the art for the cause effect relationship that is taught above." This conclusory statement does not follow since the Examiner has not established a desirability in the art for these coating rates nor has the Examiner established that these coating rates can be generally achieved in the art. There is not evidence of record (either in an affidavit under 37 C.F.R. 1.104(d)(2) or in a cited reference) to support the Examiner's suggestion.

Because of the shortcomings described in the Group 1 claims section and the particular shortcomings of the references with respect to method for coating a substrate where the amount of particles deposited upon the substrate is at least 5 or at least 25 grams per hour, the Examiner has failed to present a case of prima facie obviousness of claims 34, 39-41, 50-51, 55-56 and 60-61 over the combined teachings of the Akedo patent in view of the Bi patent. Accordingly, withdrawal of the obviousness rejection of the Group 5 claims (claims 34, 39-41, 50-51, 55-56 and 60-61) based on the combination of the Bi reference and the Akedo reference is required by law, and hereby requested by the Applicants.

E. Group 6 Claims

Claim 42 relates to a method for coating a substrate with multiple product streams. As noted above with regard to the Group 1 claims, there is no motivation to combine the cited references in the manner suggested by the Examiner, the combination of the references suggested by the Examiner yields an inoperable or incompatible system, and the combined disclosures do not provide a reasonable expectation of success. These arguments apply equally to the present Group 5 claims. Furthermore, the claimed features of the Group 6 claim are not taught or suggested by the cited references, taken alone or in combination, and this provides an additional basis for no reasonable expectation of success.

The Examiner asserted in the Office Action of April 19, 2002 at page 6, that the use of multiple reactant and product streams to coat a substrate would have been obvious to increase deposition rate. There is not evidence of record (either in an affidavit under 37 C.F.R. 1.104(d)(2) or in a cited reference) to support the Examiner's suggestion. Moreover, this argument is **inconsistent** with the obviousness of claim 42 since claim 42 indicates that the multiple streams are deposited at sequential locations on the substrate. To deposit the particles to increase deposition rate would not relate to depositions at sequential locations on the substrate.

The Akedo patent does not teach, disclose or suggest a method for coating a substrate with multiple product streams, let alone such a method wherein the multiple product streams are deposited at sequential locations on the substrate. Nothing in the Bi patent corrects this clear deficiency of the Akedo patent, as the Bi patent does not teach a method for coating a substrate, let alone such a method comprising multiple product streams or such a method wherein the multiple product streams are deposited at sequential locations on the substrate. This provides a further basis for showing that there is no reasonable expectation of success in the combination of these cited references.

Because of the shortcomings described in the Group 1 claims section and the particular shortcomings of the references with respect to method for coating a substrate with multiple product streams, the Examiner has failed to present a case of prima facie obviousness of Claim 42 over the combined teachings of the Akedo patent in view of the Bi patent. Accordingly, withdrawal of the obviousness rejection of the Group 6 claim (claim 42) based on the combination of the Bi reference and the Akedo reference is required by law, and hereby requested by the Applicants.

F. Conclusions

Since the Examiner has failed to make out a prima facie case of obviousness based on the combination of the Akedo patent and the Bi patent based on the remarks above, Applicants respectfully request withdrawal of the rejection of claims 18-29, 33-42, 44, 46-51, 55-57 and 59-61 under 35 U.S.C. § 103(a) as being unpatentable over Akedo in view of Bi.

III. REJECTIONS UNDER 35 U.S.C. § 103(a) OVER LEHMAN, AKEDO, BI AND KAMBE

The Examiner rejected claims 30, 43, 45, 52, and 58 under 35 U.S.C. § 103(a) as being unpatentable over U.S. patent 6,097,144 to Lehman (the Lehman patent) in view of the Akedo patent and the Bi patent, and in further view of PCT application WO 99/23189 to Kambe et al. (the Kambe PCT application). A copy of the Lehman patent is provided in Appendix E and a copy of the Kambe PCT application is provided in Appendix F.

The Examiner cited the Lehman patent for disclosing the production of a glass coating from a frit and for the proposition that there is a need for producing uniform glass coatings. The Examiner cited the Bi patent for disclosing nanoparticles with exploitable chemical and mechanical properties. The Examiner asserts that the combination of the Akedo patent and the

Bi patent teaches a process of producing coatings by nanoparticles. The Examiner cited the Kambe application for disclosing the production of silicon oxide nanoparticles using an apparatus similar to the Bi apparatus. See the final Office Action of 4/19/2002 at pages 7-8. Furthermore, the Examiner has asserted that “Kambe, Bi, and Akedo are sufficient alone in teaching that the Akedo and Bi apparatus is capable of producing uniform glass coatings. Lehman, the primary reference, teaches the need for producing a uniform glass coating.” Final Office Action of 4/19/2002 at page 13.

Applicants assert that the Lehman patent and the Kambe PCT application do not make up for the clear deficiencies of the Akedo patent and the Bi patent, as described in Section II above in the discussion regarding the Group 1 claims. As noted above with regard to the Group 1 claims in Section II (directed to a method of coating a substrate), there is no motivation to combine the cited Akedo and Bi references in the manner suggested by the Examiner, the combination of the Akedo and Bi references suggested by the Examiner yields an inoperable or incompatible system, and the combined disclosures of the Akedo and Bi references do not provide a reasonable expectation of success.

Although the Kambe PCT application describes apparatuses similar to the apparatus in the Bi patent, the Kambe PCT application and the Lehman patent, taken alone or in combination, do not provide any more guidance to motivate the combination with the Akedo patent, or to teach how to combine the teachings of the Akedo patent and the Bi patent, or to provide a reasonable expectation of success. Thus, the Kambe PCT application and the Lehman patent do not make up for the deficiencies of the combination with the Akedo patent and the Bi patent recited above. Accordingly, the arguments recited above (e.g., there is no motivation to combine the cited Akedo and Bi references in the manner suggested by the Examiner, the combination of the Akedo and Bi references suggested by the Examiner yields an inoperable or incompatible

system, and the combined disclosures of the Akedo and Bi references do not provide a reasonable expectation of success) apply equally to the present claims 30, 43, 45, 52 and 58.

Furthermore, claimed features of claims 30, 43, 45, 52, and 58 are not taught or suggested by the cited references, taken alone or in combination, and this provides an additional basis for no reasonable expectation of success.

Applicants believe that the combination suggested by the Examiner is the result of impermissible hindsight reasoning using Applicants' specification as a template, and that the combined disclosures of the references do not render Applicants' claimed invention prima facie obvious, because there is no motivation to combine the references in the manner suggested by the Examiner, because the combination of the references suggested by the Examiner yields an inoperable or incompatible system, because the references do not provide a reasonable expectation of success, and/or because claimed features are not taught or suggested by the cited references. Applicants respectfully request reconsideration of the rejection based on the following comments.

A. Group 1 Claims

Claims 30 and 43 relate to a method of coating a substrate. As discussed in the introduction of this Section III, there is no motivation to combine the cited Akedo and Bi references (let alone the cited Akedo, Bi, Kambe and Lehman references) in the manner suggested by the Examiner, the combination of the Akedo and Bi references (let alone the combination of the cited Akedo, Bi, Kambe and Lehman references) suggested by the Examiner yields an inoperable or incompatible system, and the combined disclosures of the Akedo and Bi references (let alone the cited Akedo, Bi, Kambe and Lehman references) do not provide a reasonable expectation of success. Furthermore, claimed features of claims 30 and 43 are not

taught or suggested by the cited references, taken alone or in combination, and this provides an additional basis for no reasonable expectation of success.

With respect to claims 30, the Akedo patent does not teach, disclose or suggest a method of forming a glass coating comprising heating a particle coating where the particle coating is formed by a method of coating a substrate. The Akedo patent specifically discusses crystalline materials. See, for example, the abstract, column 3, lines 23-29 and column 4, lines 25-27. In contrast, the glass materials of claim 30 are amorphous, i.e., not crystalline. Thus, the Akedo patent teaches away from the invention of claim 30. Similarly, the Akedo patent teaches away from any combination that includes the Lehman patent since the Lehman patent is directed to glasses, i.e., amorphous materials. Nothing in any reference, let alone the Bi reference and the Kambe PCT application, can correct these clear deficiencies of the Akedo patent, namely that the Akedo patent teaches away from both the asserted combination of references (as applied to claim 30) and claim 30 (i.e., a method of forming a glass coating comprising heating a particle coating where the particle coating is formed by a method of coating a substrate). This provides a further basis for no reasonable expectation of success.

With respect to claim 43, the Akedo patent and the Bi patent, taken alone or in combination, do not describe silicon containing compounds or materials, let alone a method of coating a substrate with silicon containing compounds or materials. Nothing in the Kambe PCT application and the Lehman reference, taken alone or in combination, can correct these clear deficiencies of the Akedo patent and the Bi patent, taken alone or in combination, as the Kambe PCT application and the Lehman patent, taken alone or in combination, do not describe the direct coating of a substrate with silicon containing compounds or materials.

Because of the shortcomings described in the introduction of this Section III and the particular shortcomings of the references with respect to a method of forming a glass coating comprising heating a particle coating where the particle coating is formed by a method of coating a

substrate (for claim 30) and a method of coating a substrate with silicon containing compounds or materials (for claim 43), the Examiner has failed to present a case of prima facie obviousness of claims 30 and 443 over the combined teachings of the Lehman patent in view of the Akedo patent and the Bi patent, and in further view of the Kambe PCT application. Accordingly, withdrawal of the obviousness rejection of the Group 1 claims (claims 30 and 43) based on the combination of the Lehman patent in view of the Akedo patent and the Bi patent, and in further view of the Kambe PCT application is required by law, and hereby requested by the Applicants.

B. Group 2

Claim 45 relates to a method for coating a substrate comprising reacting a reactant stream, where the reactant stream is elongated in a direction along the propagation of the radiation beam. Applicants note the above arguments in Section II with respect to the patentability of the claims of Group 2 over the combined teachings of the Akedo patent and the Bi patent. As discussed in the introduction to this Section III, the Kambe PCT application and the Lehman patent do not make up for the deficiencies of the combination with the Akedo patent and the Bi patent.

Because of the shortcomings described in the arguments in Section II with respect to the patentability of the claims of Group 2 over the combined teachings of the Akedo patent and the Bi patent and the particular shortcomings of the references with respect to performing a coating process with an elongated reactant stream, the Examiner has failed to present a case of prima facie obviousness of claim 45 over the combination of the Lehman patent in view of the Akedo patent and the Bi patent, and in further view of the Kambe PCT application. Accordingly, withdrawal of the obviousness rejection of the Group 2 claim (claim 45) based on the combination of the the Lehman patent in view of the Akedo patent and the Bi patent, and in

further view of the Kambe PCT application is required by law, and hereby requested by the Applicants.

C. Group 5

Claims 52 and 58 generally relate to methods for coating a substrate where the amount of particles deposited on the substrate is at least 5 or at least 25 grams per hour. Applicants note the above arguments in Section II with respect to the patentability of the claims of Group 5 over the combined teachings of the Akedo patent and the Bi patent. As discussed in the introduction to this Section III, the Kambe PCT application and the Lehman patent do not make up for the deficiencies of the combination with the Akedo patent and the Bi patent.

Because of the shortcomings described in the arguments in Section II with respect to the patentability of the claims of Group 5 over the combined teachings of the Akedo patent and the Bi patent and the particular shortcomings of the references with respect to performing a coating process with an elongated reactant stream, the Examiner has failed to present a case of prima facie obviousness of claims 52 and 58 over the combination of the Lehman patent in view of the Akedo patent and the Bi patent, and in further view of the Kambe PCT application. Accordingly, withdrawal of the obviousness rejection of the Group 5 claims (claims 52 and 58) based on the combination of the the Lehman patent in view of the Akedo patent and the Bi patent, and in further view of the Kambe PCT application is required by law, and hereby requested by the Applicants.

D. Conclusions

For the reasons discussed above with respect to claim groups 1, 2 and 5, the Examiner has fallen short of rendering claims 30, 43, 45, 52, and 58 prima facie obvious under 35 U.S.C. § 103(a) over the Lehman patent in view of the Akedo patent and the Bi patent, and in further view

of the Kambe PCT application. Because the Examiner has failed to make a reasonable showing that there exists any motivation or likelihood of success in combining the references in the manner suggested, Applicants respectfully submit that the Examiner has engaged in a piecemeal reconstruction of the Applicants' claimed invention by using Applicants' invention as a template and selecting existing features from the references. This is improper hindsight based reasoning, and as a result the obvious rejection of claims 30, 43, 45, 52, and 58 under 35 U.S.C. § 103(a) must be withdrawn.

IV. REJECTIONS UNDER 35 U.S.C. § 103(a) OVER TRAN, LEHMAN, AKEDO, BI AND KAMBE

The Examiner rejected claims 31 and 32 (Group 4 claims) under 35 U.S.C. § 103(a) as being unpatentable over U.S. patent 6,074,888 to Tran et al. (the Tran patent) in view of the Lehman patent, and further in view of Akedo and Bi in view of the Kambe PCT application. A copy of the Tran patent can be found at Appendix G.

The Examiner asserted that "Tran et al. teaches that in order to produce an optical component, it is required to produce an optical component layer, which is typically glass. Then photolithography is used to fabricate the optical component. Tran et al. fails to give the details of the optical layer. As was taught previously, the Lehman, Akedo et al., Bi et al. and Kambe et al. references can all be combined to teach a method of producing a glass coating." Office Action of 10/22/2001 at page 8. Applicants maintain that the combined disclosures of the cited references do not establish the prima facie obviousness of Applicants' claimed invention. Applicants respectfully request reconsideration of the rejection in view of the following comments.

As described above in the introduction of Section III, the Lehman patent, the Akedo patent, the Bi patent and the Kambe application do not disclose, teach, suggest or motivate a

method of coating a substrate, let alone a method of forming a glass coating comprising heating a particle coating where the particle coating is formed according to **the** method of coating a substrate or even a method of forming an optical component on a substrate surface comprising removing a portion of the glass coating formed according to **the** method of forming a glass coating. Since the Tran patent does not describe particle coatings or a method of coating a substrate, the Tran patent does not make up for the deficiencies in the other references with respect to the method of coating a substrate and derivative methods based thereon.

Since the cited references are not properly combinable because there is no motivation to combine the cited additional references with the Bi reference and the Akedo reference, the combination of the cited additional references with the Bi reference and the Akedo reference yields an inoperable or internally inconsistent system, and there is no reasonable expectation of success in the combination of additional references with the Bi reference and the Akedo reference, and since the cited references, taken alone or in combination, do not teach, motivate or suggest the claimed method of forming an optical component on a substrate surface as disclosed and claimed by Applicants, the combined disclosures of the five cited references do not establish a prima facie case of obviousness. Because the Examiner has failed to establish a prima facie case of obviousness, the rejection of claims 31 and 32 under 35 U.S.C. § 103(a) as being unpatentable over the Tran patent in view of the Lehman patent and further in view of the Akedo patent and the Bi patent in view of the Kambe patent must be withdrawn.

V. REJECTIONS UNDER 35 U.S.C § 103(a) OVER BÖRNER AND BI

The Examiner rejected claims 18-29, 39-41, 50 and 51 under 35 U.S.C. § 103(a) as being unpatentable over U.S. patent 6,032,871 to Börner et al. (the Börner patent) in view of the Bi patent. A copy of the Börner patent can be found at Appendix H.

The Examiner asserted that, "Börner teaches a process of spraying two different materials to a substrate by applying differing charges to each particle stream. Börner is silent to how these particles streams are produced. However, Bi teaches that nanoparticles exhibit exploitable chemical and mechanical properties that are different from larger sized particles, such as increased smoothness and thinner coatings. The apparatus taught by Bi is advantageous to use in order to produce these nanoparticles due to its efficient use of resources. Therefore, it would have been obvious at the time the invention was made to a person having ordinary skill in the art to use the apparatus of Bi to produce the particle streams of Börner." Office Action of 4/19/2002 at page 10.

However, Applicants maintain that the suggested combination does not follow from the teachings of the references and that the Examiner has failed to establish a prima facie case of obviousness with respect to this rejection. Specifically, the references are not properly combinable because there is no motivation to combine the references in the manner suggested by the Examiner, and the Bi reference teaches away from a combination with the Börner patent, and, even if properly combinable, the references do not provide a reasonable expectation of success. Applicants respectfully request reconsideration of the rejections based on the following comments.

A. Group 1 Claims

Claims 18-21, 23, 25, 28-29 relate to a method of coating a substrate. The cited references are not properly combinable because there is no motivation to combine the references in the manner suggested by the Examiner, the Börner patent is nonanalogous art, and the Bi reference teaches away from a combination with the Börner patent.

With respect to the motivation to combine the references, Applicants assert that there is no explicit motivation to combine the references. Concerning any implicit motivation, the

Examiner asserted that the necessary motivation is provided by the production benefit of efficient use of resources disclosed in the Bi patent. Office Action of 4/19/2002 at page 10.

Analogous to the discussion above in the context of the combination of the Bi reference with the Akedo reference, the benefits of the efficient use of resources that result from the use of the Bi apparatus are obtained in full if the particles are collected from the Bi apparatus and transferred to the Börner apparatus. Moreover, the “efficient use in resources” of particle production would be substantially offset by the inventive effort that would be required to perform the dramatic redesign of the cited apparatuses to have them function together in the substitution suggested by the Examiner. The cited references do not provide any guidance on this reconstruction. In addition, there is no evidence of record (either in an affidavit under 37 C.F.R. 1.104(d)(2) or in a cited reference) that a person of ordinary skill in the art would consider a particle generation apparatus as a reasonable substitute within an apparatus that is directed to the electrospray art.

Furthermore, there is no implicit motivation since the references suggest the sequential use of the apparatuses first to produce particles and then to perform coating with the resulting powder. In addition, the Börner patent teaches the coating with a **charged** particle stream, i.e., electrostatic spraying. The Bi patent does not teach or suggest the production of a charged particle stream. Thus, there is no motivation to combine the teachings in the references.

With respect to the Börner patent being nonanalogous art, the Börner patent discusses the use of electrospray deposition. In the Office Action of 4/19/2002, the Examiner incorrectly asserted that the Börner patent is silent with respect to how the particle streams for coating are produced. In response to Applicants contrary assertions, the Examiner noted in the Advisory Action that the Börner patent is not limited to the use of a corona and/or a triboelectric spray guns. Nevertheless, the Börner patent is clearly directed to the electrospray art, and not any particle coating approach.

With respect to the Bi reference teaching away from a combination with the Börner patent, the Examiner further asserts that the Bi patent teaches the generation of an aerosol particle stream. However, this aerosol particle stream is confined within a particles production chamber under particle chamber properties to produce the desired particles. Contrary to the Examiner's assertions, the particle flow from the Bi apparatus cannot be arbitrarily attached to other apparatuses without possibly adversely altering particle production. The Bi patent is clear that particle production is very sensitive to the properties within the reaction chamber. See, for example, column 4, lines 60-65. The properties in the reaction chamber generally depend on the properties of the resulting flow of product particles. Therefore, the Bi patent teaches away from the combination suggested by the Examiner.

Moreover, even if properly combinable, the combination of references suggested by the Examiner lacks a reasonable expectation of success. The Börner patent specifically teaches that the particle streams are charged particle streams for electrostatic deposition, see throughout. The Examiner has not indicated how the teachings can be combined to result in the disclosed charged particle streams for deposition. While the Examiner has asserted that the spray guns themselves generate the charges particle stream, the Examiner has not explained how this follows from the teachings in the art. Since the Börner patent teaches coating with a charged particle stream and the Bi patent does not disclose a charged particle stream, the Examiner has not provided a reasonable basis to combine the teachings of the references.

While the Examiner has fallen far short of an appropriate explanation of the combined teachings, at the very most, the Examiner has asserted an invitation to experiment based on the teachings of the references. Such an invitation to experiment does not provide a reasonable expectation of success in practicing Applicants' claimed invention.

In conclusion, the Examiner has failed to establish prima facie obviousness, because (a) the cited references are not properly combinable because there is no motivation to combine the

references in the manner suggested by the Examiner and the Bi reference teaches away from a combination with the the Börner patent, and (b) even if properly combined, the references do not provide a reasonable expectation of success.

B. Group 2 Claims

Claims 22, 24 and 26 relate to a method for coating a substrate comprising reacting a reactant stream, where the reactant stream is elongated in a direction along the propagation of the radiation beam. With respect to claims 22, 24 and 26, the arguments above with respect to Group 1 claims apply equally. Thus, (a) the cited references are not properly combinable because there is no motivation to combine the references in the manner suggested by the Examiner, and the Bi reference teaches away from a combination with the the Börner patent, and (b) even if properly combined, the references do not provide a reasonable expectation of success.

In addition, claims 22, 24 and 26 provide a further basis for the combined references not providing a reasonable expectation of success. Specifically, the Börner patent does not teach or suggest coating with a particle stream elongated in one dimension. Therefore, with respect to these claims another hurdle must be overcome with respect to combining the disclosures since the references are further silent with respect to how to combine a reactant stream from an elongated inlet and a coating apparatus based on a charged particle stream.

Since the Börner patent and the Bi patent are not properly combinable as suggested by the Examiner for the reasons set forth above, and because there is no teaching on how to combine the teaching of the references to form Applicants' claimed invention, and, even if the cited references are properly combinable, there is no reasonable expectation of success by combining the references as suggested by the Examiner, the Examiner has failed to establish prima facie obviousness of the claims of Group 2.

C. Group 3 Claims

Claim 27 relates to a method for coating a substrate in which the reactant inlet moves relative to the substrate. With respect to claim 27, the arguments above with respect to Group 1 claims apply equally. Thus, (a) the cited references are not properly combinable because there is no motivation to combine the references in the manner suggested by the Examiner, the Börner patent is nonanalogous art, and the Bi reference teaches away from a combination with the the Börner patent, and (b) even if properly combined, the references do not provide a reasonable expectation of success.

Furthermore, claimed features of claim 27 are not taught or suggested by the cited references, taken alone or in combination, and this provides an additional basis for no reasonable expectation of success. With respect to claim 27, the Examiner has not indicated how the references teach the movement of the reactant inlet to perform coating. This provides a further basis for no reasonable expectation of success.

Since the Börner patent and the Bi patent are not properly combinable as suggested by the Examiner for the reasons set forth above with respect to Group I, and, even if the cited references are properly combinable, there is no reasonable expectation of success by combining the references as suggested by the Examiner and claimed features of claim 27 are not taught or suggested by the cited references, taken alone or in combination, the Examiner has failed to establish prima facie obviousness of the claim of Group 3.

D. Group 5 Claims

Claims 39-41, 50 and 51 generally relate to methods for coating a substrate where the amount of particles deposited on the substrate is at least 5 or at least 25 grams per hour. With respect to claims 39-41, 50 and 51, the arguments above with respect to Group 1 claims apply equally. Thus, (a) the cited references are not properly combinable because there is no

motivation to combine the references in the manner suggested by the Examiner and the Bi reference teaches away from a combination with the the Börner patent, and (b) even if properly combined, the references do not provide a reasonable expectation of success.

Furthermore, claimed features of the Group 5 claims are not taught or suggested by the cited references, taken alone or in combination, and this provides an additional basis for no reasonable expectation of success. With respect to claims 39-41, 50 and 51, the Examiner asserted that the feature of coating rate is taught by the Bi patent. However, the Bi patent is silent with respect to coating rate or coating formation generally.

Since the Börner patent and the Bi patent are not properly combinable as suggested by the Examiner for the reasons set forth above with respect to Group I, and, even if the cited references are properly combinable, there is no reasonable expectation of success by combining the references as suggested by the Examiner and claimed features of claims 39-41, 50 and 51 are not taught or suggested by the cited references, taken alone or in combination, the Examiner has failed to establish prima facie obviousness of the claim of Group 5.

E. Conclusions

Since the Examiner has fallen short of establishing prima facie obviousness of the claims, the rejection of claims 18-29, 39-41, 50 and 51 under 35 U.S.C. § 103(a) as being unpatentable over the Börner patent in view of the Bi patent must be withdrawn.

VI. REJECTIONS UNDER 35 U.S.C. § 103(a) OVER BÖRNER, AKEDO AND BI

The Examiner rejected claims 53 and 54 (Group 6 claims) under 35 U.S.C. § 103(a) as being unpatentable over the Börner patent in view of the Akedo patent and the Bi patent. The Examiner cited the Börner patent for disclosing the desire to have powder coatings of two different materials applied to the same substrate surface. Office Action of 4/19/2002 at page 11.

The Examiner also indicated that it would be obvious to have an “Akedo and Bi apparatus” provide each stream. However, due to the deficiencies of the cited references disclosed above, the combined teachings of the references do not render the claims prima facie obvious. Applicants respectfully request reconsideration of the rejection based on the following comments.

As described in detail above, the combination of the Akedo patent and the Bi patent does not lead to a “Akedo and Bi apparatus” because there is no motivation to combine the cited Akedo and Bi references in the manner suggested by the Examiner, the combination of the Akedo and Bi references suggested by the Examiner yields an inoperable or internally incompatible system, and the combined disclosures of the Akedo and Bi references do not provide a reasonable expectation of success. Furthermore, both the devices from the Akedo patent and the laser pyrolysis apparatus from the Bi patent have significant differences from the electrostatic spray guns of the Börner patent. Specifically, the Börner patent teaches the production of two particle streams with **different charges**, one positively charged and one negatively charged. The Examiner has not indicated how particle streams from a hypothetical “Akedo and Bi apparatus” would generate appropriate positive and or negative particle streams to practice the Börner process.

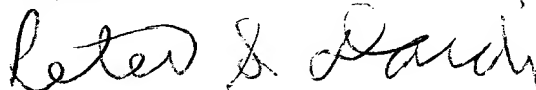
Based on the lack of motivation to combine, the combination's formation of an inoperable or internally inconsistent system, and the lack of likelihood of success in combining the references as suggested by the Examiner, it is clear that the Examiner is reconstructing Applicants' claimed invention using Applicants' disclosure as a template. To simply pick desired features to reconstruct the claimed invention is not reasonable without guidance from the prior art on how to connect the disparate technologies, and this hindsight reconstruction is contrary to established legal precedent.

Thus, because the Examiner has failed to establish prima facie obviousness, the rejection under 35 U.S.C. § 103(a) as being unpatentable over Borner in view of Akedo and Bi must be withdrawn.

CONCLUSIONS AND REQUEST FOR RELIEF

Applicants submit that claims 18-61 are unobvious over the prior art of record. Applicants believe that the Examiner has failed to establish prima facie unpatentability of any of the claims. Thus, Applicants respectfully request the reversal of the rejections of claims 18-61 and the allowance of claims 18-61.

Respectfully submitted,



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Peter S. Dardi
Peter S. Dardi, Ph.D.

- A. Pending Claims
- B. Assignment
- C. U.S. Patent No. 6,280,802 to Akedo et al.
- D. U.S. Patent No. 5,958,348 to Bi et al.
- E. U.S. Patent No. 6,097,144 to Lehman
- F. PCT Published Application No. WO 99/23189 to Kambe et al.
- G. U.S. Patent No. 6,074,888 to Tran et al.
- H. U.S. Patent No. 6,032,087 to Börner et al.

APPENDIX A
PENDING CLAIMS

18. A method of coating a substrate, the method comprising:
reacting a reactant stream by directing a focused radiation beam at the reactant stream to produce a product stream comprising particles downstream from the radiation beam, wherein the particles are produced by the reaction and wherein the reaction is driven by energy from the radiation beam;
directing the product stream to a substrate; and
moving the substrate relative to the product stream to coat the substrate.
19. The method of claim 18 wherein the radiation beam is generated by a light source.
20. The method of claim 18 wherein the radiation beam is generated by a laser.
21. The method of claim 18 further comprising pumping on the reaction chamber to maintain flow through the reaction chamber.
22. The method of claim 18 wherein the reactant stream is elongated in a direction along the propagation of the radiation beam.
23. The method of claim 18 wherein the substrate is mounted on a stage that moves relative to a product stream.

24. The method of claim 23 wherein the reactant stream is elongated in a direction along the propagation of the radiation beam to produce a line of product particles that are simultaneously deposited on the substrate and wherein relative movement of the stage sweeps the line across the substrate.
25. The method of claim 23 further comprising moving the substrate from the path of the reactant stream and placing another substrate in the path of the product stream.
26. The method of claim 18 wherein the reactant stream is elongated and wherein a line of light propagates to intersect the elongated reactant stream.
27. The method of claim 18 wherein the reactant inlet moves relative to the substrate such that motion of the reactant inlet sweeps the product particles across the substrate.
28. The method of claim 18 wherein the product stream passes through a conduit prior to reaching the substrate and wherein the conduit moves relative to the substrate with motion of the conduit sweeping the product particles across the substrate.
29. The method of claim 18 wherein an external field is applied to direct the product stream.
30. A method of forming a glass coating comprising heating a particle coating at a temperature and for a period of time sufficient to fuse the particles into a glass and where the particle coating is formed according to the method of claim 18.

31. A method of forming an optical component on a substrate surface, the method comprising removing a portion of a glass coating formed according to the method of claim 30 to form the optical component.
32. The method of claim 31 wherein the removing of a portion of the glass coating is performed by photolithography.
33. A method of coating a substrate comprising:
generating a reactant stream with a cross section perpendicular to the propagation direction characterized by a major axis and a minor axis, the major axis being at least a factor of two greater than the minor axis;
reacting the reactant stream to form a product stream of particles; and
directing the stream of particles to a substrate, wherein flow of the product stream is maintained other than by pumping on the substrate.
34. The method of claim 33 wherein at least about 25 grams per hour are deposited onto the substrate.
35. The method of claim 33 wherein the reaction is driven by a light beam.
36. The method of claim 33 wherein the major axis is at least a factor of ten greater than the minor axis.
37. The method of claim 33 wherein the flow of the stream of particles is maintained by momentum of the product stream.

38. The method of claim 33 wherein the flow of the stream of particles is maintained by pumping out a chamber and wherein the substrate is located within the chamber.

39. A method of coating a substrate having a diameter greater than about 5 cm, the method comprising:

reacting a reactant stream to form a product stream comprising product particles,

wherein the particles are produced by the reaction; and

depositing simultaneously a stream of particles over the entire surface of the

substrate and wherein at least about 5 grams per hour of particles are

deposited onto the substrate.

40. The method of claim 39 wherein the product stream of particles is defocused with an external field.

41. The method of claim 40 wherein the external field is generated by thermal gradient generator or an electric field generator.

42. A method of coating a substrate comprising:

simultaneously generating multiple product streams by chemical reaction driven by

a light beam; and

depositing the multiple product streams simultaneously on a moving substrate at sequential locations on the substrate.

43. The method of claim 18 wherein the reactant stream comprises a silicon precursor.
44. The method of claim 18 wherein the reactant stream comprises a metal precursor.
45. The method of claim 33 wherein the reactant stream comprises a silicon precursor.
46. The method of claim 33 wherein the reactant stream comprises a metal precursor.
47. The method of claim 35 wherein the light beam comprises infrared light.
48. The method of claim 33 wherein the substrate is moved relative to the product stream while directing the stream of particles to the substrate to coat different portions of the substrate.
49. The method of claim 33 wherein the substrate is moved relative to the product stream while directing the stream of particles to the substrate to coat the surface of the substrate in one pass of the substrate through the product stream.
50. The method of claim 39 wherein at least about 25 grams per hour are deposited onto the substrate.
51. The method of claim 39 wherein the reaction is driven by energy from a radiation beam.

52. The method of claim 39 wherein the reactant stream comprises a silicon precursor.
53. The method of claim 42 wherein at least two of the multiple product streams comprise product particles with the same composition.
54. The method of claim 42 wherein at least one of the multiple product streams comprise product particles with a different composition from product particle in another of the multiple product streams.
55. A method of coating a surface of a substrate, the method comprising:
reacting a reactant stream to product a product stream comprising particles wherein the particles are produced by the reaction; and
directing the product stream to the substrate to deposit at least about 5 grams per hour onto the substrate.
56. The method of claim 56 wherein the reaction is driven by energy from a radiation beam.
57. The method of claim 56 wherein the reactant stream has a cross section perpendicular to the propagation direction characterized by a major axis and a minor axis, the major axis being at least about a factor of two greater than the minor axis.
58. The method of claim 56 wherein the reactant stream comprises a silicon precursor.

59. The method of claim 56 wherein the substrate is moved relative to the product stream while directing the stream of particles to the substrate.

60. The method of claim 56 wherein the directing of the product stream to the substrate deposits at least about 25 grams per hour onto the substrate.

61. The method of claim 56 wherein the substrate does not permit gas to pass through.

ASSIGNMENT

Attorney Docket No.

N19.12-0038

WHEREAS, I, Xiangxin Bi, of San Ramon, California; Ronald J. Mosso, of Fremont, California; Chiruvolo Shivkumar, of Sunnyvale, California; Sujeet Kumar of Fremont, California, James T. Gardner of Cupertino, California; Seung M. Lim, of Livermore, California; and William E. McGovern, of Livermore, California, have invented certain new and useful improvements as described in an application entitled COATING FORMATION BY REACTIVE DEPOSITION for Letters Patent of the United States, the application having been executed on even date herewith, and/or being identifiable in the United States Patent and Trademark Office by Serial No. 09/715,935, filed November 17, 2000; and

WHEREAS, NanoGram Corporation, a corporation organized and existing under the laws of the State of California, and having offices at 46774 Lakeview Boulevard, Fremont, California 94538 ("Assignee") is desirous of acquiring the entire right, title and interest in and to the invention, the application, and any and all Letters Patent or similar legal protection, foreign or domestic, to be obtained therefor;

NOW, THEREFORE, for good and valuable consideration, the receipt and adequacy of which is hereby acknowledged, I transfer to Assignee, its successors and assigns, my entire right, title and interest in and to the invention, the above-identified application, corresponding domestic and foreign applications, all Letters Patent or similar legal protection issuing thereon, and all rights and benefits under any applicable treaty or convention; and I authorize the Commissioner of Patents and Trademarks of the United States or foreign equivalent thereof to issue the Letters Patent or similar legal protection to the Assignee.

I authorize the Assignee, its successors and assigns, to insert in this instrument the filing date and serial number of the application when ascertained.


I authorize the Assignee, its successors and assigns, or anyone it may properly designate, to apply for Letters Patent or similar legal protection, in its own name if desired, in any and all foreign countries.

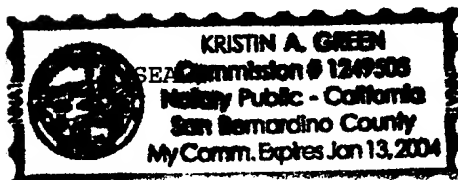
I represent to the Assignee, its successors and assigns, that I have not and shall not execute any writing or do any act whatsoever conflicting with this Assignment. I, my executors or administrators, will at any time upon request, without additional consideration, but at the expense of the Assignee, its successors and assigns, execute such additional writings and do such additional acts as the Assignee, its successors and assigns, may deem desirable to perfect its enjoyment of this grant, and render all assistance in making application for and obtaining, maintaining, and enforcing the Letters Patent or similar legal protection on the invention in any and all countries.


Xiangxin BI

STATE OF CALIFORNIA)
) ss.
COUNTY OF ALAMEDA)

Subscribed and sworn to before me, a Notary Public, this ____ day
of MAY, 2001.


Notary Public

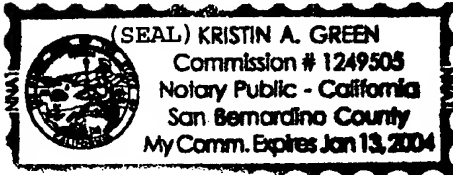


Ronald J. Mosso
Ronald J. Mosso

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COUNTY OF ALAMEDA)

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Kristin A. Green
Notary Public

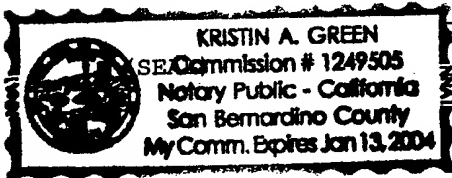


Chiruvola Shivkumar
Chiruvola
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of MAY, 2001.

Kristin A. Green
Notary Public

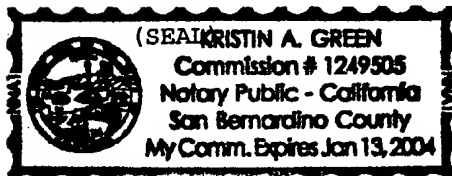


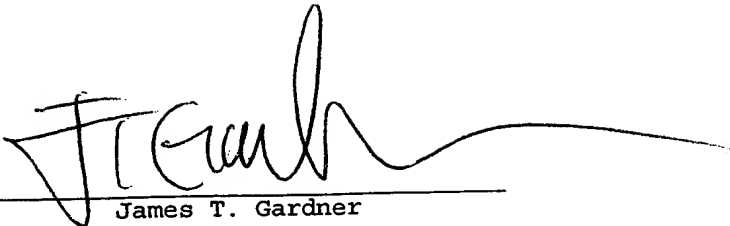
Sujeet Kumar
Sujeet Kumar

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COUNTY OF ALAMEDA)

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of MAY, 2001.

Kristin A. Green
Notary Public

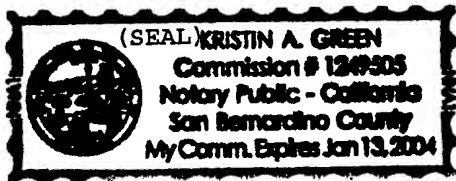



James T. Gardner

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COUNTY OF ALAMEDA)

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of MAY, 2001.


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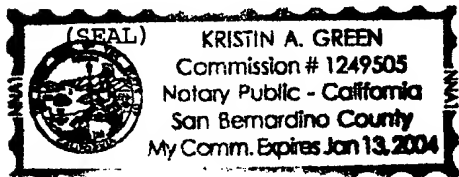


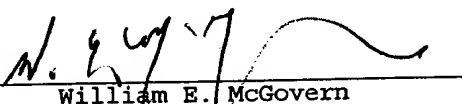

Seung M. Lim

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) ss.
COUNTY OF ALAMEDA)

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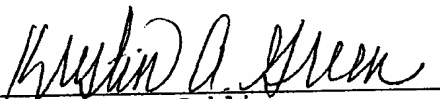

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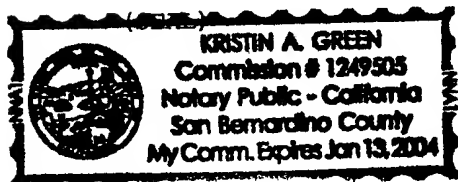



William E. McGovern

STATE OF CALIFORNIA)
) ss.
COUNTY OF ALAMEDA)

Subscribed and sworn to before me, a Notary Public, this 17 day
of MAY, 2001.


Notary Public



PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the application of:

Attorney Docket No.: 2950.16US02

BI et al.

Application No.: 09/715,935

Examiner: E. Fuller

Filed: November 17, 2000

Group Art Unit: 1762

For: COATING FORMATION BY REACTIVE DEPOSITION

ASSIGNMENT TRANSMITTAL

BOX ASSIGNMENTS

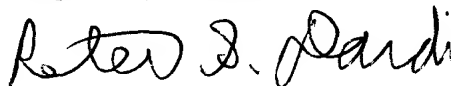
Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Enclosed please find an Assignment regarding the above-identified application. Please record the assignment of the invention from Xiangxin Bi, Ronald J. Mosso, Chiruvolu Shivkumar, Sujeet Kumar, James T. Gardner, Seung M. Lim, and William E. McGovern to NanoGram Corporation. Also enclosed is a check in the amount of \$40.00 to cover the recording fee.

Please charge any additional fees or credit any overpayment to our Deposit Account No. 16-0631.

Respectfully submitted,



Peter S. Dardi, Ph.D.
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Please grant any extension of time necessary for entry; charge any fee due to Deposit Account No. 16-0631.

CERTIFICATE OF MAILING

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Peter S. Dardi
Peter S. Dardi

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(21) International Application Number: PCT/US98/23021 (22) International Filing Date: 29 October 1998 (29.10.98) (30) Priority Data: 08/961,735 31 October 1997 (31.10.97) US (71) Applicant: NANOGRAM CORPORATION [US/US]; 46776 Lakeview Boulevard, Fremont, CA 94538 (US). (72) Inventors: KAMBE, Nobuyuki; 840 Hobart Street, Menlo Park, CA 94025 (US). BI, Xiangxin; 677 Greylyn Drive, San Remon, CA 94583 (US). (74) Agents: DARDI, Peter, S. et al.; Westman, Champlin & Kelly, P.A., International Centre, Suite 1600, 900 Second Avenue South, Minneapolis, MN 55402-3319 (US).		(81) Designated States: CN, JP, KR, SG, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
(54) Title: ABRASIVE PARTICLES FOR SURFACE POLISHING (57) Abstract Polishing compositions are described that are appropriate for fine polishing to very low tolerances. The polishing compositions include particles with small diameters with very narrow distributions in size and effectively no particles with diameters several times larger than the average diameter. Furthermore, the particles generally have very high uniformity with respect to having a single crystalline phase. Preferred particles have an average diameter less than about 200 nm. Laser pyrolysis processes are described for the production of the appropriate particles including metal oxides, metal carbides, metal sulfides, SiO ₂ and SiC.		

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ABRASIVE PARTICLES FOR SURFACE POLISHING

Field of the Invention

5 The invention relates to abrasive compositions useful for surface polishing, especially mechanochemical polishing, and methods for producing abrasive particles.

Background of the Invention

10 Technological advances have raised the demand for improved material processing with strict tolerances on processing parameters. In particular, smooth surfaces are required in a variety of applications in electronics, tool production and many other industries. The substrates requiring polishing can involve hard materials such as ceramics, glass and metal. As
15 miniaturization continues even further, even more precise polishing will be required. Current submicron technology requires polishing accuracy on a nanometer scale. Precise polishing technology can employ mechanochemical polishing involving a polishing
20 composition that acts by way of a chemical interaction of the substrate with the polishing agents as well as an abrasive effective for mechanical smoothing of the surface.

Summary of the Invention

25 Improved polishing compositions are described for smoothing surfaces to very low tolerances. The polishing compositions are based on small particles with a very narrow distribution of particle diameters to provide for more control over the polishing process.
30 Furthermore, a collection of preferred particles have effectively no particles with significantly larger diameters. In addition, the preferred particles have a very high level of purity with respect to a single crystalline phase. Laser pyrolysis provides for the

-2-

production of preferred particles. Laser pyrolysis not only provides for the production of particles with preferred properties for abrasive applications but also for efficient and controlled production of the
5 particles. These features provide for cost effective commercialization of the improved abrasive compositions.

In a first aspect, the invention features a composition comprising a dispersion of particles, the particles including metal compounds and having an
10 average particle diameter from about 5 nm to about 200 nm and a distribution of diameters such that at least about 95 percent of the particles have a diameter greater than about 60 percent of the average diameter and less than about 140 percent of the average diameter.
15 The particles can be dispersed in an aqueous or nonaqueous solution. The particles preferably comprise a composition selected from the group consisting of SiO_2 , SiC , TiO_2 , Fe_3C , Fe_7C_3 , Fe_2O_3 , Fe_3O_4 , MoS_2 , MoO_2 , WC , WO_3 , and WS_2 . The particles preferably have an average
20 diameter less than about 100 nm.

In another aspect, the invention features a composition comprising a dispersion of particles, the particles including metal compounds with an average particle diameter from about 5 nm to about 200 nm and a
25 single crystalline phase with a uniformity of at least about 90 percent by weight. The particles can be dispersed in an aqueous or nonaqueous solution. The particles preferably have a single phase uniformity of at least about 95 percent by weight, more preferably at
30 least about 99 percent by weight and even more preferably at least about 99.9 percent by weight.

In another aspect, the invention features a composition comprising a dispersion of particles, the particles including metal carbides or metal sulfides and

-3-

having an average particle diameter from about 5 nm to about 200 nm.

In another aspect, the invention features a method of smoothing a surface comprising the step of
5 polishing the surface with a composition of the invention, as summarized above and further described below. The polishing can be performed with a polishing pad and can involve a motorized polisher.

In another aspect, the invention features a
10 method of producing SiO_2 particles including the step of pyrolyzing a molecular stream comprising a silicon compound precursor, an oxidizing agent and a radiation absorbing gas in a reaction chamber, where the pyrolysis is driven by heat absorbed from a laser beam. The
15 silicon compound precursor can include a compound that is selected from the group consisting of CH_3SiCl_3 . The laser beam preferably is supplied by a CO_2 laser. The molecular stream preferably is generated by a nozzle elongated in one dimension.

In another aspect, the invention features a
20 method of producing iron oxide particles comprising the step of pyrolyzing a molecular stream comprising a iron compound precursor, an oxidizing agent and a radiation absorbing gas in a reaction chamber, where the pyrolysis
25 is driven by heat absorbed from a laser beam. The iron precursor can comprise $\text{Fe}(\text{CO})_5$.

Other features and advantages are evident from the detailed description of the invention and claims presented below.

30 Brief Description of the Drawings

Fig. 1 is a schematic, sectional view of an embodiment of a laser pyrolysis apparatus taken through the middle of the laser radiation path. The upper

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insert is a bottom view of the injection nozzle, and the lower insert is a top view of the collection nozzle.

Fig. 2 is a schematic, perspective view of a reaction chamber of an alternative embodiment of the laser pyrolysis apparatus, where the materials of the chamber are depicted as transparent to reveal the interior of the apparatus.

Fig. 3 is a sectional view of the reaction chamber of Fig. 2 taken along line 3-3.

Fig. 4 is a schematic, sectional view of an oven for heating vanadium oxide particles, in which the section is taken through the center of the quartz tube.

Description of the Preferred Embodiments

Methods have been developed for producing nanoscale particles with a small distribution of particle diameters. These particles generally have a single crystalline phase and a high level of uniformity. These particles are useful as abrasives, especially for polishing hard surfaces that have restrictive tolerance requirements with respect to smoothness. The small diameters together with the narrow spread in distribution of diameters provide for polishing to generate a surface with reduced degree of surface roughness. The particles can be used in polishing compositions containing other polishing agents that supplement the abrasive properties of the particles alone. The polishing compositions can be used for manual polishing or for polishing with a motorized polisher.

Suitable abrasive particles generally are ceramics, although not necessarily electrical insulators, and can include a variety of metal oxides, sulfides and carbides as well as silica compounds. Preferred particles are relatively hard. The particle

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can include, for example, one of the following compounds: SiO_2 , SiC , TiO_2 , Fe_2O_3 , Fe_3O_4 , Fe_3C , Fe_7C_3 , MoS_2 , MoO_2 , WC , WO_3 , and WS_2 . A mixture of abrasive particles of different chemical composition can be used to form a polishing formulation. The appropriate composition of the abrasive particles depends on the composition of the substrate to be polished.

Laser pyrolysis, as described below, is an excellent process for efficiently producing suitable ceramic particles with a narrow distribution of average particle diameters. A basic feature of successful application of laser pyrolysis for the production of appropriate small scale particles is production of a molecular stream containing a precursor compound, a radiation absorber and a reactant serving as an oxygen, sulfur or carbon source. The molecular stream is pyrolyzed by an intense laser beam. As the molecular stream leaves the laser beam, the particles are rapidly quenched.

Laser pyrolysis provides for formation of phases of metal compounds that may be difficult to form under thermodynamic equilibrium conditions. The particles produced by laser pyrolysis also are suitable for optional further processing to alter and/or improve the properties of the particles.

A. Particle Production

Laser pyrolysis has been discovered to be a valuable tool for the production of nanoscale silicon dioxide, silicon carbide and metal oxide, metal carbide and metal sulfide particles of interest. In addition, the particles produced by laser pyrolysis are a convenient material for further processing to expand the pathways for the production of desirable metal compound particles. Thus, using laser pyrolysis alone or in

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combination with additional processes, a wide variety of silicon dioxide, silicon carbide and metal oxide, metal carbide and metal sulfide particles can be produced. In some cases, alternative production pathways can be followed to produce comparable particles.

The reaction conditions determine the qualities of the particles produced by laser pyrolysis. The reaction conditions for laser pyrolysis can be controlled relatively precisely in order to produce particles with desired properties. The appropriate reaction conditions to produce a certain type of particles generally depend on the design of the particular apparatus. Nevertheless, some general observations on the relationship between reaction conditions and the resulting particles can be made.

Increasing the laser power results in increased reaction temperatures in the reaction region as well as a faster quenching rate. A rapid quenching rate tends to favor production of high energy phases. Similarly, increasing the chamber pressure also tends to favor the production of higher energy structures. Also, increasing the concentration of the reactant serving as the oxygen, carbon or sulfur source in the reactant stream favors the production of metal oxides, metal carbides or metal sulfides with increased amounts of oxygen, carbon or sulfur.

Reactant gas flow rate and velocity of the reactant gas stream are inversely related to particle size so that increasing the reactant gas flow rate or velocity tends to result in smaller particle size. Also, the growth dynamics of the particles have a significant influence on the size of the resulting particles. In other words, different crystal forms of a product compound have a tendency to form different

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size particles from other crystal forms under relatively similar conditions. Laser power also influences particle size with increased laser power favoring larger particle formation for lower melting materials and smaller particle formation for higher melting materials.

Appropriate precursor compounds generally include metal or silicon compounds with reasonable vapor pressures, i.e., vapor pressures sufficient to get desired amounts of precursor vapor in the reactant stream. The vessel holding the precursor compounds can be heated to increase the vapor pressure of the metal (silicon) compound precursor, if desired. Preferred silicon precursors include, for example, CH_3SiCl_3 . Preferred iron precursors include, for example, $\text{Fe}(\text{CO})_5$.

Preferred reactants serving as oxygen sources include, for example, O_2 , CO , CO_2 , O_3 and mixtures thereof. Preferred reactants serving as carbon sources include, for example, C_2H_4 and C_6H_6 . Preferred reactants serving as sulfur sources include, for example, H_2S . The reactant compound from the oxygen, carbon or sulfur source should not react significantly with the metal compound precursor prior to entering the reaction zone since this generally would result in the formation of large particles.

Laser pyrolysis can be performed with a variety of optical laser frequencies. Preferred lasers operate in the infrared portion of the electromagnetic spectrum. CO_2 lasers are particularly preferred sources of laser light. Infrared absorbers for inclusion in the molecular stream include, for example, C_2H_4 , NH_3 , SF_6 , SiH_4 and O_3 . O_3 can act as both an infrared absorber and as an oxygen source. Similarly, C_2H_4 can act as both an infrared absorber and as a carbon source. The radiation absorber, such as the infrared absorber, absorbs energy

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from the radiation beam and distributes the energy to the other reactants to drive the pyrolysis.

Preferably, the energy absorbed from the radiation beam increases the temperature at a tremendous rate, many times the rate that energy generally would be produced even by strongly exothermic reactions under controlled condition. While the process generally involves nonequilibrium conditions, the temperature can be described approximately based on the energy in the absorbing region. The laser pyrolysis process is qualitatively different from the process in a combustion reactor where an energy source initiates a reaction, but the reaction is driven by energy given off by an exothermic reaction.

An inert shielding gas can be used to reduce the amount of reactant and product molecules contacting the reactant chamber components. Appropriate shielding gases include, for example, Ar, He and N₂.

The production of iron carbides by laser pyrolysis has been described in Bi et al., "Nanocrystalline α -Fe, Fe₃C, and Fe₇C₃ produced by CO₂ laser pyrolysis," J. Mater. Res. 8:1666-1674 (1993), incorporated herein by reference.

An appropriate laser pyrolysis apparatus generally includes a reaction chamber isolated from the ambient environment. A reactant inlet connected to a reactant supply system produces a molecular stream through the reaction chamber. A laser beam path intersects the molecular stream at a reaction zone. The molecular stream continues after the reaction zone to an outlet, where the molecular stream exits the reaction chamber and passes into a collection system. Generally, the laser is located external to the reaction chamber,

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and the laser beam enters the reaction chamber through an appropriate window.

Referring to Fig. 1, a particular embodiment 100 of a pyrolysis apparatus involves a reactant supply system 102, reaction chamber 104, collection system 106 and laser 108. Reactant supply system 102 includes a source 120 of precursor compound. For liquid precursors, a carrier gas from carrier gas source 122 can be introduced into precursor source 120, containing liquid precursor to facilitate delivery of the precursor. The carrier gas from source 122 preferably is either an infrared absorber or an inert gas and is preferably bubbled through the liquid, precursor compound. The quantity of precursor vapor in the reaction zone is roughly proportional to the flow rate of the carrier gas.

Alternatively, carrier gas can be supplied directly from infrared absorber source 124 or inert gas source 126, as appropriate. The reactant providing the oxygen, carbon or sulfur is supplied from reactant source 128, which can be a gas cylinder or other suitable container. The gases from the precursor source 120 are mixed with gases from reactant source 128, infrared absorber source 124 and inert gas source 126 by combining the gases in a single portion of tubing 130. The gases are combined a sufficient distance from reaction chamber 104 such that the gases become well mixed prior to their entrance into reaction chamber 104. The combined gas in tube 130 passes through a duct 132 into rectangular channel 134, which forms part of an injection nozzle for directing reactants into the reaction chamber.

Flow from sources 122, 124, 126 and 128 are preferably independently controlled by mass flow

-10-

controllers 136. Mass flow controllers 136 preferably provide a controlled flow rate from each respective source. Suitable mass flow controllers include, for example, Edwards Mass Flow Controller, Model 825 series, from Edwards High Vacuum International, Wilmington, MA.

Inert gas source 138 is connected to an inert gas duct 140, which flows into annular channel 142. A mass flow controller 144 regulates the flow of inert gas into inert gas duct 140. Inert gas source 126 can also function as the inert gas source for duct 140, if desired.

The reaction chamber 104 includes a main chamber 200. Reactant supply system 102 connects to the main chamber 200 at injection nozzle 202. The end of injection nozzle 202 has an annular opening 204 for the passage of inert shielding gas, and a rectangular slit 206 for the passage of reactant gases to form a molecular stream in the reaction chamber. Annular opening 204 has, for example, a diameter of about 1.5 inches and a width along the radial direction of about 1/16 in. The flow of shielding gas through annular opening 204 helps to prevent the spread of the reactant gases and product particles throughout reaction chamber 104.

Tubular sections 208, 210 are located on either side of injection nozzle 202. Tubular sections 208, 210 include ZnSe windows 212, 214, respectively. Windows 212, 214 are about 1 inch in diameter. Windows 212, 214 are preferably plane-focusing lenses with a focal length equal to the distance between the center of the chamber to the surface of the lens to focus the beam to a point just below the center of the nozzle opening. Windows 212, 214 preferably have an antireflective coating. Appropriate ZnSe lenses are available from

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Janos Technology, Townshend, Vermont. Tubular sections 208, 210 provide for the displacement of windows 212, 214 away from main chamber 200 such that windows 212, 214 are less likely to be contaminated by reactants or products. Window 212, 214 are displaced, for example, about 3 cm from the edge of the main chamber 200.

Windows 212, 214 are sealed with a rubber o-ring to tubular sections 208, 210 to prevent the flow of ambient air into reaction chamber 104. Tubular inlets 216, 218 provide for the flow of shielding gas into tubular sections 208, 210 to reduce the contamination of windows 212, 214. Tubular inlets 216, 218 are connected to inert gas source 138 or to a separate inert gas source. In either case, flow to inlets 216, 218 preferably is controlled by a mass flow controller 220.

Laser 108 is aligned to generate a laser beam 222 that enters window 212 and exits window 214. Windows 212, 214 define a laser light path through main chamber 200 intersecting the flow of reactants at reaction zone 224. After exiting window 214, laser beam 222 strikes power meter 226, which also acts as a beam dump. An appropriate power meter is available from Coherent Inc., Santa Clara, CA. Laser 108 can be replaced with an intense conventional light source such as an arc lamp. Preferably, laser 108 is an infrared laser, especially a CW CO₂ laser such as an 1800 watt maximum power output laser available from PRC Corp., Landing, NJ or a Coherent® model 525 (Coherent, Inc., Santa Clara, CA) with a maximum power output of 375 watts.

Reactants passing through slit 206 in injection nozzle 202 initiate a molecular stream. The molecular stream passes through reaction zone 224, where reaction involving the precursor compound takes place.

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Heating of the gases in reaction zone 224 is extremely rapid, roughly on the order of 10^5 °C/sec depending on the specific conditions. The reaction is rapidly quenched upon leaving reaction zone 224, and particles
5 228 are formed in the molecular stream. The nonequilibrium nature of the process allows for the production of particles with a highly uniform size distribution and structural homogeneity.

The path of the molecular stream continues to
10 collection nozzle 230. Collection nozzle 230 is spaced about 2 cm from injection nozzle 202. The small spacing between injection nozzle 202 and collection nozzle 230 helps reduce the contamination of reaction chamber 104 with reactants and products. Collection nozzle 230 has
15 a circular opening 232. Circular opening 232 feeds into collection system 106.

The chamber pressure is monitored with a pressure gauge attached to the main chamber. The preferred chamber pressure for the production of the
20 desired oxides, sulfides and carbides generally ranges from about 80 Torr to about 500 Torr.

Reaction chamber 104 has two additional tubular sections not shown. One of the additional tubular sections projects into the plane of the
25 sectional view in Fig. 1, and the second additional tubular section projects out of the plane of the sectional view in Fig. 1. When viewed from above, the four tubular sections are distributed roughly, symmetrically around the center of the chamber. These
30 additional tubular sections have windows for observing the inside of the chamber. In this configuration of the apparatus, the two additional tubular sections are not used to facilitate production of particles.

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Collection system 106 can include a curved channel 250 leading from collection nozzle 230. Because of the small size of the particles, the product particles follow the flow of the gas around curves.

5 Collection system 106 includes a filter 252 within the gas flow to collect the product particles. A variety of materials such as teflon, glass fibers and the like can be used for the filter as long as the material is inert and has a fine enough mesh to trap the particles.

10 Preferred materials for the filter include, for example, a glass fiber filter from ACE Glass Inc., Vineland, NJ.

Pump 254 is used to maintain collection system 106 at a selected pressure. A variety of different pumps can be used. Appropriate pumps for use as pump

15 254 include, for example, Busch Model B0024 pump from Busch, Inc., Virginia Beach, VA with a pumping capacity of about 25 cubic feet per minute (cfm) and Leybold Model SV300 pump from Leybold Vacuum Products, Export, PA with a pumping capacity of about 195 cfm. It may be

20 desirable to flow the exhaust of the pump through a scrubber 256 to remove any remaining reactive chemicals before venting into the atmosphere. The entire apparatus 100 can be placed in a fume hood for ventilation purposes and for safety considerations.

25 Generally, the laser remains outside of the fume hood because of its large size.

The apparatus is controlled by a computer. Generally, the computer controls the laser and monitors the pressure in the reaction chamber. The computer can

30 be used to control the flow of reactants and/or the shielding gas. The pumping rate is controlled by either a manual needle valve or an automatic throttle valve inserted between pump 254 and filter 252. As the chamber pressure increases due to the accumulation of

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particles on filter 252, the manual valve or the throttle valve can be adjusted to maintain the pumping rate and the corresponding chamber pressure.

5 The reaction can be continued until sufficient particles are collected on filter 252 such that the pump can no longer maintain the desired pressure in the reaction chamber 104 against the resistance through filter 252. When the pressure in reaction chamber 104 can no longer be maintained at the desired value, the
10 reaction is stopped, and the filter 252 is removed. With this embodiment, about 3-75 grams of particles can be collected in a single run before the chamber pressure can no longer be maintained. A single run generally can last from about 10 minutes to about 3 hours depending on
15 the type of particle being produced and the particular filter. Therefore, it is straightforward to produce a macroscopic quantity of particles, i.e., a quantity visible with the naked eye.

The reaction conditions can be controlled
20 relatively precisely. The mass flow controllers are quite accurate. The laser generally has about 0.5 percent power stability. With either a manual control or a throttle valve, the chamber pressure can be controlled to within about 1 percent.

25 The configuration of the reactant supply system 102 and the collection system 106 can be reversed. In this alternative configuration, the reactants are supplied from the bottom of the reaction chamber, and the product particles are collected from
30 the top of the chamber. This alternative configuration can result in a slightly higher collection of product for particles that are buoyant in the surrounding gases. In this configuration, it is preferable to include a curved section in the collection system so that the

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collection filter is not mounted directly above the reaction chamber.

A apparatus similar to laser pyrolysis embodiment 100 has been used to produce a variety of
5 vanadium oxide nanoparticles in different oxidation states. These are described in commonly assigned U.S. Patent Application Serial Number 08/897,778, filed July 21, 1997, incorporated herein by reference.

An alternative design of a laser pyrolysis
10 apparatus has been described. See, commonly assigned U.S. Patent Application No. 08/808,850, entitled "Efficient Production of Particles by Chemical Reaction," incorporated herein by reference. This alternative design is intended to facilitate production
15 of commercial quantities of particles by laser pyrolysis. A variety of configurations are described for injecting the reactant materials into the reaction chamber.

The alternative apparatus includes a reaction
20 chamber designed to minimize contamination of the walls of the chamber with particles, to increase the production capacity and to make efficient use of resources. To accomplish these objectives, the reaction chamber conforms generally to the shape of an elongated
25 reactant inlet, decreasing the dead volume outside of the molecular stream. Gases can accumulate in the dead volume, increasing the amount of wasted radiation through scattering or absorption by nonreacting molecules. Also, due to reduced gas flow in the dead
30 volume, particles can accumulate in the dead volume causing chamber contamination.

The design of the improved reaction chamber 300 is schematically shown in Figs. 2 and 3. A reactant gas channel 302 is located within block 304. Facets 306

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of block 304 form a portion of conduits 308. Another portion of conduits 308 join at edge 310 with an inner surface of main chamber 312. Conduits 308 terminate at shielding gas inlets 314. Block 304 can be repositioned or replaced, depending on the reaction and desired conditions, to vary the relationship between the elongated reactant inlet 316 and shielding gas inlets 314. The shielding gases from shielding gas inlets 314 form blankets around the molecular stream originating from reactant inlet 316.

The dimensions of elongated reactant inlet 316 preferably are designed for high efficiency particle production. Reasonable dimensions for the reactant inlet for the production of the relevant oxide, sulfide and carbide particles, when used with a 1800 watt CO₂ laser, are from about 5 mm to about 1 meter.

Main chamber 312 conforms generally to the shape of elongated reactant inlet 316. Main chamber 312 includes an outlet 318 along the molecular stream for removal of particulate products, any unreacted gases and inert gases. Tubular sections 320, 322 extend from the main chamber 312. Tubular sections 320, 322 hold windows 324, 326 to define a laser beam path 328 through the reaction chamber 300. Tubular sections 320, 322 can include shielding gas inlets 330, 332 for the introduction of shielding gas into tubular sections 320, 322.

The improved apparatus includes a collection system to remove the particles from the molecular stream. The collection system can be designed to collect a large quantity of particles without terminating production or, preferably, to run in continuous production by switching between different particle collectors within the collection system. The

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collection system can include curved components within the flow path similar to curved portion of the collection system shown in Fig. 1. The configuration of the reactant injection components and the collection system can be reversed such that the particles are collected at the top of the apparatus.

As noted above, properties of the product particles can be modified by further processing. For example, oxide nanoscale particles can be heated in an oven in an oxidizing environment or an inert environment to alter the oxygen content and/or crystal structure of the metal oxide. The processing of metal oxide nanoscale particles in an oven is further discussed in commonly assigned, U.S. Patent Application Ser. No. 08/897,903, filed July 21, 1997, entitled "Processing of Vanadium Oxide Particles With Heat," incorporated herein by reference.

In addition, the heating process can be used possibly to remove adsorbed compounds on the particles to increase the quality of the particles. It has been discovered that use of mild conditions, i.e., temperatures well below the melting point of the particles, results in modification of the stoichiometry or crystal structure of metal oxides without significantly sintering the particles into larger particles.

A variety of apparatuses can be used to perform the heat processing. An example of an apparatus 400 to perform this processing is displayed in Fig. 4. Apparatus 400 includes a tube 402 into which the particles are placed. Tube 402 is connected to a reactant gas source 404 and inert gas source 406. Reactant gas, inert gas or a combination thereof to

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produce the desired atmosphere are placed within tube 402.

Preferably, the desired gases are flowed through tube 402. Appropriate reactant gases to produce an oxidizing environment include, for example, O₂, O₃, CO, CO₂ and combinations thereof. The reactant gas can be diluted with inert gases such as Ar, He and N₂. The gases in tube 402 can be exclusively inert gases if an inert atmosphere is desired. The reactant gases may not result in changes to the stoichiometry of the particles being heated.

Tube 402 is located within oven or furnace 408. Oven 408 maintains the relevant portions of the tube at a relatively constant temperature, although the temperature can be varied systematically through the processing step, if desired. Temperature in oven 408 generally is measured with a thermocouple 410. The silicon oxide, silicon carbide, metal oxide, metal sulfide or metal carbide particles can be placed in tube 402 within a vial 412. Vial 412 prevents loss of the particles due to gas flow. Vial 412 generally is oriented with the open end directed toward the direction of the source of the gas flow.

The precise conditions including type of oxidizing gas (if any), concentration of oxidizing gas, pressure or flow rate of gas, temperature and processing time can be selected to produce the desired type of product material. The temperatures generally are mild, i.e., significantly below the melting point of the material. The use of mild conditions avoids interparticle sintering resulting in larger particle sizes. Some controlled sintering of the particles can be performed in oven 408 at somewhat higher temperatures to produce slightly larger average particle diameters.

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For the processing of titanium dioxide, for example, the temperatures preferably range from about 50°C to about 1000°C, and more preferably from about 50°C to about 500°C and even more preferably from about 50°C to about 200°C. The particles preferably are heated for about 1 hour to about 100 hours. Some empirical adjustment may be required to produce the conditions appropriate for yielding a desired material.

B. Particle Properties

A collection of particles of interest generally has an average diameter of less than a micron, preferably from about 5 nm to about 500 nm, more preferably from about 5 nm to about 100 nm, and even more preferably from about 5 nm to about 50 nm. The particles usually have a roughly spherical gross appearance. Upon closer examination, the particles generally have facets corresponding to the underlying crystal lattice. Nevertheless, the particles tend to exhibit growth that is roughly equal in the three physical dimensions to give a gross spherical appearance. Diameter measurements on particles with asymmetries are based on an average of length measurements along the principle axes of the particle. The measurements along the principle axes preferably are each less than about 1 micron for at least about 95 percent of the particles, and more preferably for at least about 98 percent of the particles.

Because of their small size, the particles tend to form loose agglomerates due to van der Waals and other electromagnetic forces between nearby particles. Nevertheless, the nanometer scale of the particles (i.e., primary particles) is clearly observable in transmission electron micrographs of the particles. For crystalline particles, the particle size generally

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corresponds to the crystal size. The particles generally have a surface area corresponding to particles on a nanometer scale as observed in the micrographs. Furthermore, the particles manifest unique properties due to their small size and large surface area per weight of material. For example, TiO_2 nanoparticles generally exhibit altered absorption properties based on their small size, as described in commonly assigned and simultaneously filed U.S. Patent Application, entitled "Ultraviolet Light Block and Photocatalytic Materials," incorporated herein by reference.

As produced, the particles preferably have a high degree of uniformity in size. As determined from examination of transmission electron micrographs, the particles generally have a distribution in sizes such that at least about 95 percent of the particles have a diameter greater than about 40 percent of the average diameter and less than about 160 percent of the average diameter. Preferably, the particles have a distribution of diameters such that at least about 95 percent of the particles have a diameter greater than about 60 percent of the average diameter and less than about 140 percent of the average diameter.

Furthermore, essentially no particles have an average diameter greater than about 5 times the average diameter. In other words, the particle size distribution effectively does not have a tail indicative of a small number of particles with significantly larger sizes. This is a result of the small reaction region and corresponding rapid quench of the particles. Preferably, less than about 1 particle in 10^6 have a diameter greater than about 5 times the average diameter. The narrow size distributions and lack of a

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tail in the distributions can be exploited in a variety of applications, as described below.

5 In addition, the particles generally have a very high uniformity with respect to displaying a single crystalline phase and corresponding stoichiometry within the phase. Also, the silicon oxide, silicon carbide, metal oxide, metal sulfide and metal carbide particles produced by the above methods generally have a purity greater than the reactant gases because the crystal formation process tends to exclude contaminants from the lattice. Furthermore, particles produced by laser pyrolysis generally have been found to have a high degree of crystallinity. High degrees of crystallinity can result in harder and/or more abrasion resistant particles, which may be desirable for some applications. In view of all of these characteristics, especially small particle size, uniformity in size, crystalline phase and purity, the particles described herein are particularly suitable for abrasive applications.

20 Although under certain conditions mixed phase material can be formed, laser pyrolysis generally is effective to produce single phase, crystalline particles with a high degree of uniformity. Primary particles generally consist of single crystals of the material. The single phase, single crystal properties of the particles can be used advantageously along with the uniformity and narrow size distribution. Under certain conditions, amorphous particles are formed by laser pyrolysis. The amorphous particles can be useful for certain applications, and the amorphous particles generally can be heated under mild conditions to form crystalline particles.

The attributes of some of the compositions of particular interest are described. Iron is known to

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exist in several different oxidation states. For example, iron oxides are known with stoichiometries of Fe_2O_3 , Fe_3O_4 and FeO . FeO has a cubic crystal structure similar to NaCl , and Fe_3O_4 has a cubic, inverse spinel crystal structure. $\alpha\text{-Fe}_2\text{O}_3$ has a trigonal crystal structure while $\gamma\text{-Fe}_2\text{O}_3$ has a cubic, spinel crystal structure that transforms to $\alpha\text{-Fe}_2\text{O}_3$ above 600°C . Similarly, iron carbides have been observed with stoichiometries of Fe_3C (cementite-orthorhombic), Fe_7C_3 (triclinic and hexagonal, pseudo-hexagonal or orthorhombic), Fe_5C_2 (Hagg carbide - monoclinic), Fe_2C (cementite, orthorhombic), Fe_{20}C_9 , Fe_4C and $\epsilon\text{-carbide}$ (Fe_xC , $2 < x < 3$, hexagonal). The conditions used in laser pyrolysis generally can be altered to select the desired forms of the iron compounds. The conditions in a particular apparatus for the selective production of Fe_3C and Fe_7C_3 , have been described in the Bi et al., J. Material Res. article, supra.

Silicon oxides can have stoichiometries of SiO (amorphous) and SiO_2 . Silicon dioxide can have a variety of crystal structures such as hexagonal (quartz), trigonal, monoclinic (coesite), amorphous and combinations thereof. Silicon carbide similarly can have a variety of crystal structures.

Molybdenum and tungsten also exhibits multiple oxidation states. For example, molybdenum oxides can have stoichiometries of, for example, MoO_2 (monoclinic, deformed rutile), MoO_3 (triclinic), Mo_3O_8 and Mo_8O_{23} . Similarly, Molybdenum sulfides can have stoichiometries of, for example, Mo_2S_3 , MoS_2 , MoS_3 and Mo_2S_5 . Tungsten oxides can have stoichiometries of, for example, WO_2 (tetragonal, deformed rutile), WO_3 (orthorhombic), $\text{W}_{18}\text{O}_{49}$ and $\text{W}_{20}\text{O}_{58}$. Tungsten carbides are known with

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stoichiometries of W_2C (hexagonal) and WC (α -tetragonal and β -cubic).

C. Polishing Compositions

A variety of polishing compositions can advantageously incorporate the abrasive particles described above. In its simplest form, the polishing composition can just involve the abrasive particles, produced as described above. More preferably, the abrasive particles are dispersed in an aqueous or nonaqueous solution. The solution generally includes a solvent such as water, alcohol, acetone or the like. The abrasive particles should not be significantly soluble in the solvent. The polishing composition generally includes from about 0.05 percent to about 50 percent, and preferably from about 0.1 percent to about 10 percent by weight abrasive particles.

The solvents preferably have a low level of contaminants. In particular, water used as a solvent should be deionized and/or distilled. Any solvent should be greater than about 99 percent pure, and more preferably at least about 99.9 percent pure. The polishing composition preferably is free from any contaminants, i.e., any composition not included for effectuating the polishing process. In particular, the polishing composition should be free from particulate contaminants, which are not soluble in the solvent.

The polishing compositions can include other components to assist with the polishing process. For example, the polishing composition can include a slurry of colloidal silica. The use of colloidal silica for polishing hard substrates is described in U.S. Patent No. 5,228,886, incorporated herein by reference. Colloidal silica has been suggested to chemically react with certain surfaces. Silica particles produced by

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laser pyrolysis are ideally suited for the production of colloidal silica due to all of the properties described above. When using colloidal silica along with additional abrasive particles such as those described
5 above, the polishing composition preferably includes from about 0.05 to about 5 percent abrasive particles and more preferably from about 0.1 to about 2 percent by weight.

The polishing composition can be acidic or
10 basic to improve the polishing characteristics. For polishing metals an acidic pH generally is preferred, for example, in the range from about 3.0 to about 3.5. A variety of acids can be used such as glacial acetic acid. For polishing oxide surfaces a basic polishing
15 composition can be used, for example, with a pH from about 10.5 to about 11.

Preferred abrasive particles include silicon oxide, silicon carbide, metal oxides, metal sulfides and metal carbides with average diameters less than about
20 100 nm and more preferably from about 5 nm to about 50 nm. Preferred abrasive particles include compounds such as SiO_2 , SiC , TiO_2 , Fe_2O_3 , Fe_3O_4 , Fe_3C , Fe_7C_3 , MoS_2 , MoO_2 , WC , WO_3 , and WS_2 . Also, preferred abrasive particles have a relatively narrow diameter distribution and an
25 effective cut of particle diameters that are several times larger than the average diameter, as described above. The particular composition of abrasive particles should be selected such that the particles have an appropriate hardness for the surface to be polished as
30 well as an appropriate distribution of diameters to obtain efficiently the desired smoothness. Abrasive particles that are too hard can result in undesired scratches in the surface while particles that are too soft may not be suitably abrasive.

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The composition of the abrasive particles should also provide for removal of the polishing compositions after completion of the polishing. One approach to cleaning polished surfaces involves
5 dissolving the abrasive particles with a cleaning solution that does not damage the polished surface.

The polishing compositions can be used for mechanical or mechanochemical polishing that is performed manually or using a powered polishing machine.
10 In either case, the polishing composition is generally applied to a polishing pad or cloth to perform the polishing. Any of a variety of mechanical polishers can be used, for example, vibratory polishers and rotary polishers.

15 The polishing compositions are particularly useful for the polishing of substrate surfaces for the production of integrated circuits. As the density of integrated circuits on a single surface increases, the tolerances for smoothness of the corresponding
20 substrates become more stringent. Therefore, it is important that polishing process is able to remove small surface discontinuities prior to applying circuit patterns onto the substrate. The small size and uniformity of the abrasive particles disclosed herein
25 are particularly suitable in polishing compositions for these applications. SiO₂ particles are suitable for the polishing of silicon based semiconductor substrates. Similarly, layered structures involving patterned portions of insulating layers and conducting layers can
30 be simultaneously planarized, as described in U.S. Patent No. 4,956,313, incorporated herein by reference.

The embodiments described above are intended to be representative and not limiting. Additional embodiments of the invention are within the claims. As

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will be understood by those skilled in the art, many changes in the methods and apparatus described above may be made by the skilled practitioner without departing from the spirit and scope of the invention, which should
5 be limited only as set forward in the claims which follow.

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What is claimed is:

1. A polishing composition comprising a dispersion of particles, the particles comprising metal compounds and having an average particle diameter from
5 about 5 nm to about 200 nm and a distribution of diameters such that at least about 95 percent of the particles have a diameter greater than about 60 percent of the average diameter and less than about 140 percent of the average diameter.
- 10 2. The polishing composition of claim 1 wherein the particles are dispersed in an aqueous solution.
3. The polishing composition of claim 1 wherein the particles are dispersed in a nonaqueous
15 solution.
4. The polishing composition of claim 1 wherein the particles comprise a composition selected from the group consisting of SiO_2 , SiC , TiO_2 , Fe_3C , Fe_7C_3 , Fe_2O_3 , Fe_3O_4 , MoS_2 , MoO_2 , WC , WO_3 , and WS_2 .
- 20 5. The polishing composition of claim 1 wherein the particles have an average diameter from about 5 nm to about 100 nm.
6. A method of smoothing a surface comprising the step of polishing the surface with the
25 polishing composition of claim 1.
7. The method of claim 6 wherein the polishing is performed with a polishing pad.
8. The method of claim 6 wherein the polishing is performed with a motorized polisher.
- 30 9. A polishing composition comprising a dispersion of particles, the particles comprising metal compounds with an average particle diameter from about 5 nm to about 200 nm and a single crystalline phase with a uniformity of at least about 90 percent by weight.

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10. The polishing composition of claim 9 wherein the particles comprise a composition selected from the group consisting of SiO_2 , SiC , TiO_2 , Fe_3C , Fe_7C_3 , Fe_2O_3 , Fe_3O_4 , MoS_2 , MoO_2 , WC , WO_3 and WS_2 .

5 11. The polishing composition of claim 9 wherein the particles have an average diameter from about 5 nm to about 100 nm.

12. The polishing composition of claim 9 wherein the particles have a single crystalline phase with a uniformity of at least about 95 percent by weight.

13. The polishing composition of claim 9 wherein the particles have a single crystalline phase with a purity of at least about 99 percent by weight.

15 14. The polishing composition of claim 9 wherein the particles have a single crystalline phase with a purity of at least about 99.9 percent by weight.

15. A polishing composition comprising a dispersion of particles, the particles comprising metal compounds or silicon compounds with an average particle diameter from about 5 nm to about 200 nm and effectively no particles with a diameter greater than 1 micron.

16. A polishing composition comprising a dispersion of particles, the particles comprising metal carbides or metal sulfides and having an average particle diameter from about 5 nm to about 200 nm.

17. A method of producing SiO_2 particles comprising the step of pyrolyzing a molecular stream comprising a silicon compound precursor, an oxidizing agent and a radiation absorbing gas in a reaction chamber, where the pyrolysis is driven by heat absorbed from a laser beam.

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18. The method of claim 17 wherein the silicon compound precursor comprises a compound that is selected from the group consisting of CH_3SiCl_3 .

19. The method of claim 17 wherein the laser
5 beam is supplied by a CO_2 laser.

20. The method of claim 17 wherein the molecular stream is generated by a nozzle elongated in one dimension.

21. A method of producing iron oxide
10 particles comprising the step of pyrolyzing a molecular stream comprising a iron compound precursor, an oxidizing agent and a radiation absorbing gas in a reaction chamber, where the pyrolysis is driven by heat absorbed from a laser beam.

22. The method of claim 21 wherein the iron
15 precursor comprises $\text{Fe}(\text{CO})_5$.

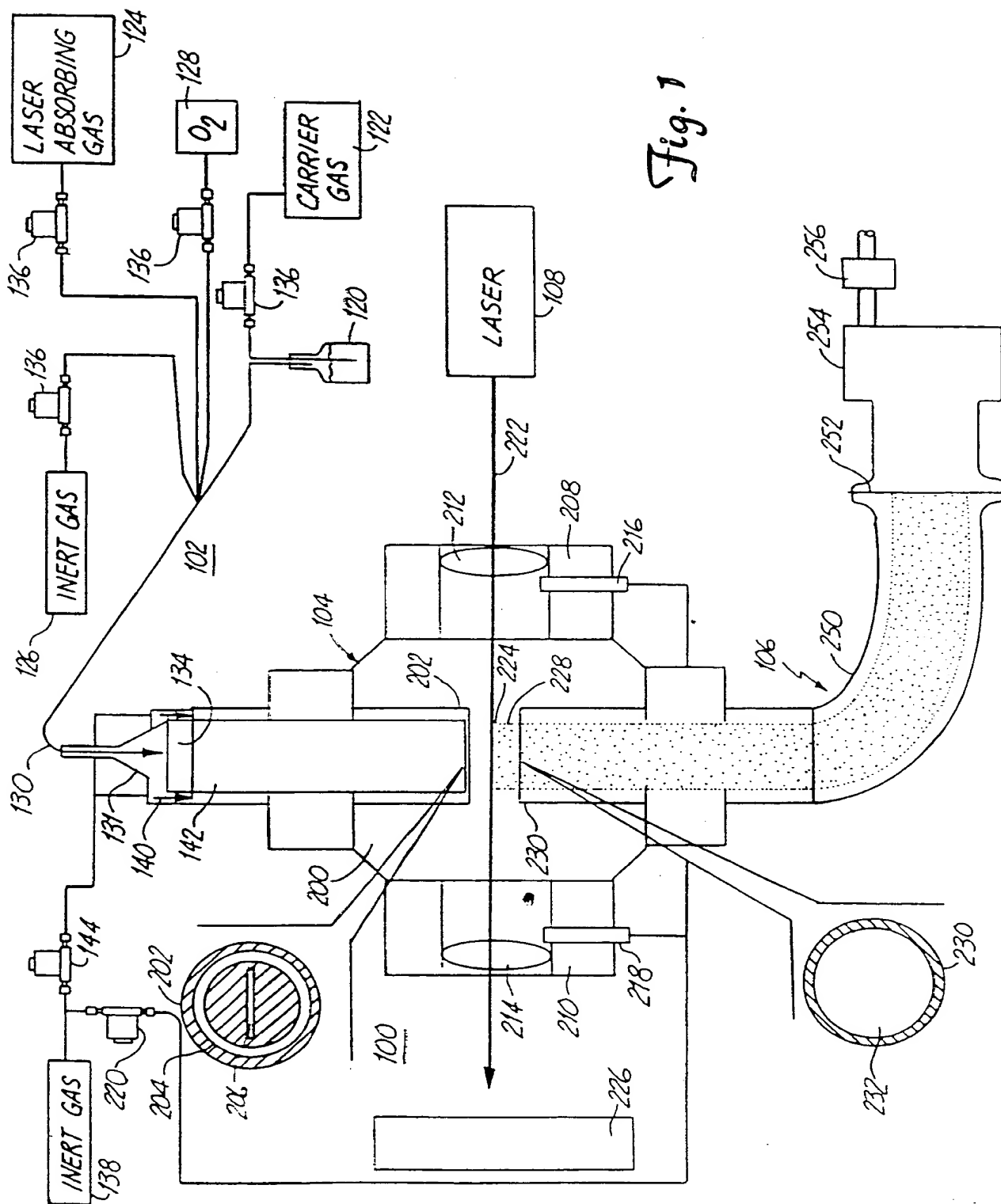


Fig. 1

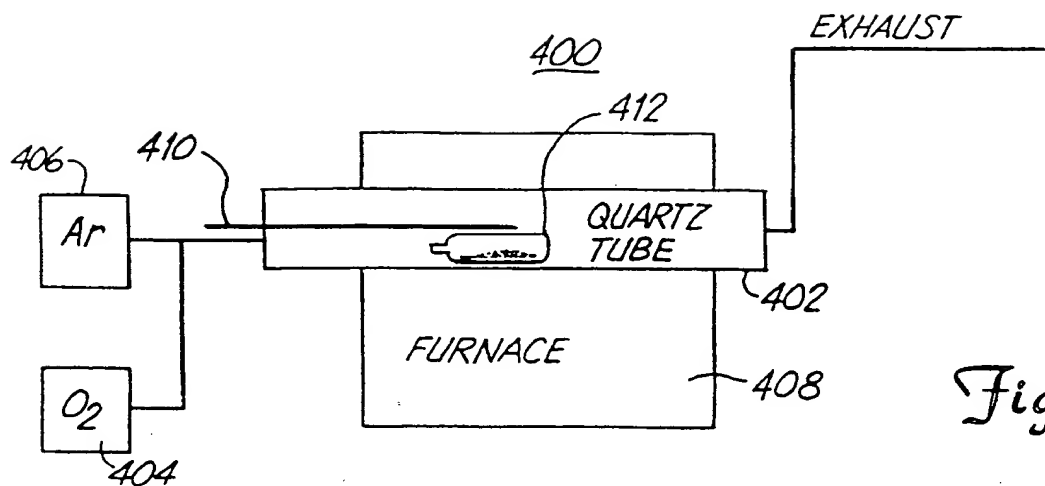
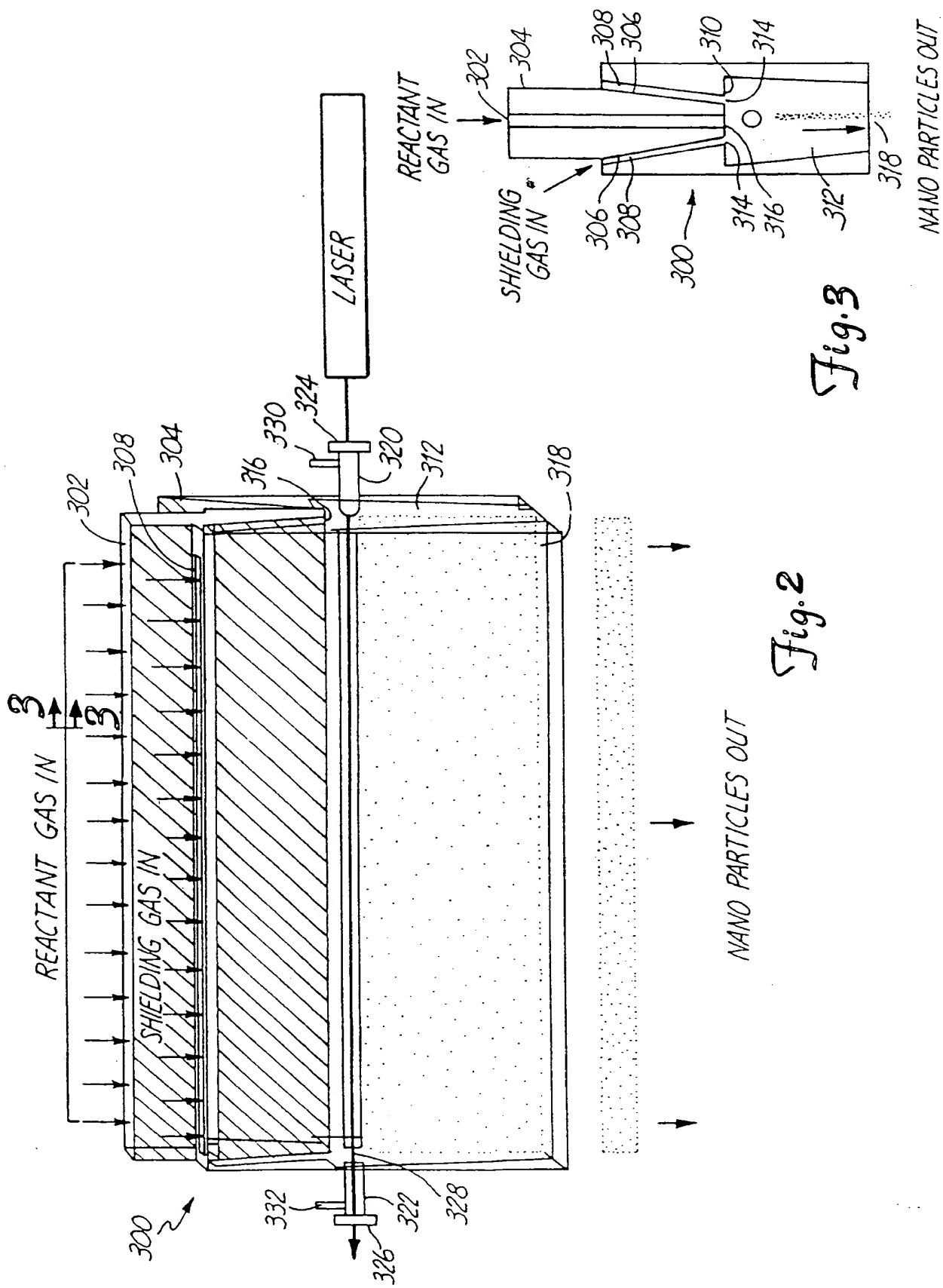
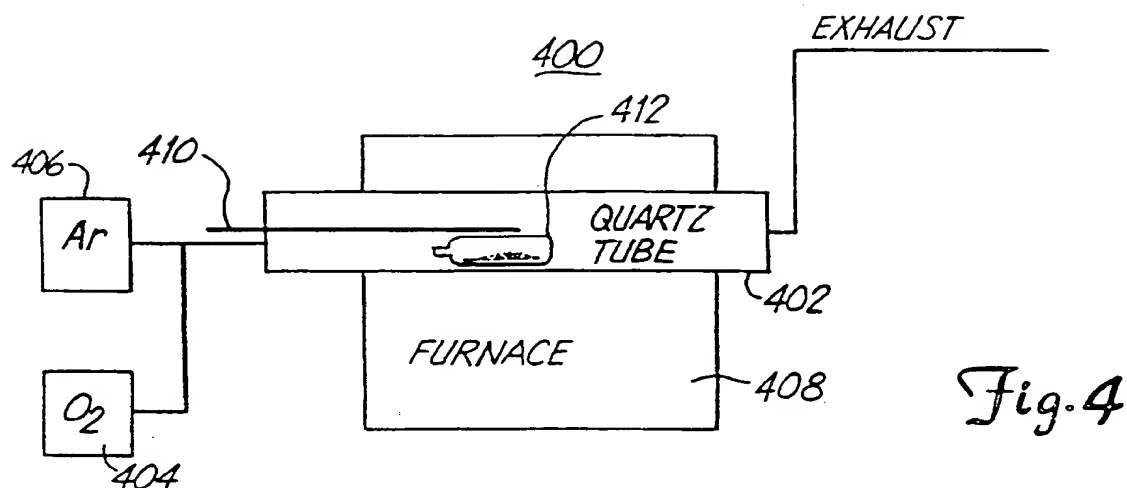


Fig. 4





INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/23021

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C09K3/14 B01J19/12 C09G1/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C09K B01J C09G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Inter. Appl. No.

PCT/US 98/23021

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X	EP 0 209 298 A (DOW CHEMICAL CO) 21 January 1987	1-3,5-9, 11-15
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INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 98/23021

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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International Application No

PCT/US 98/23021

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